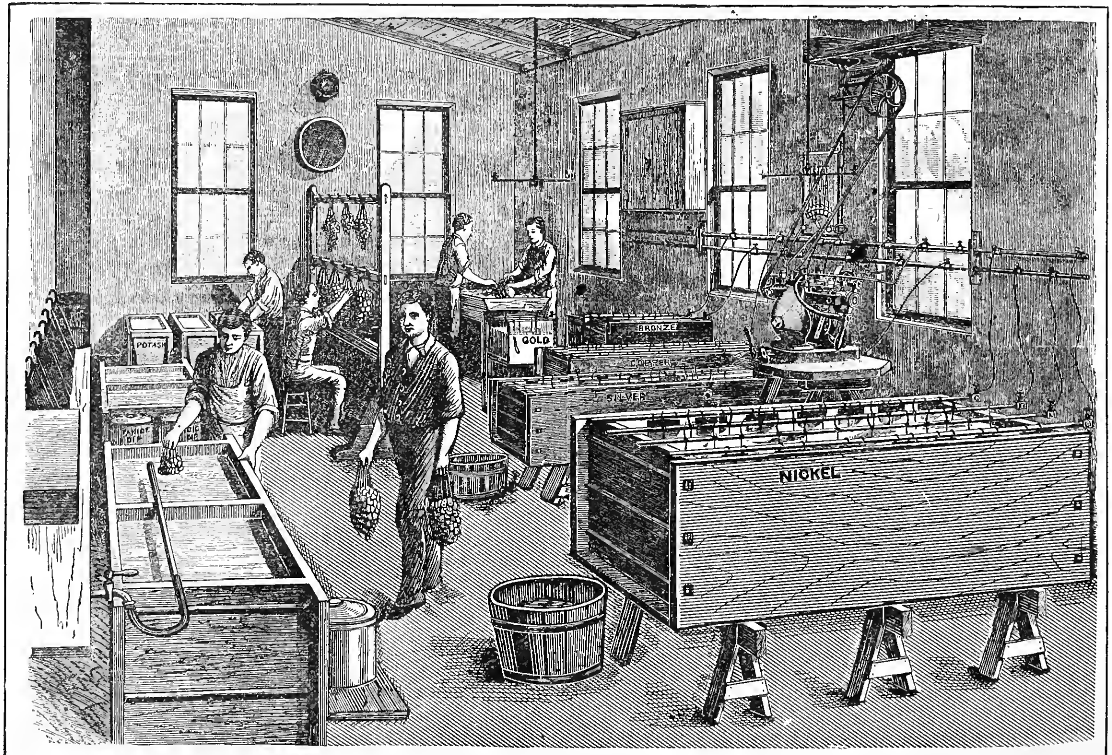
POTASH
GOLD
BRONZE
COPPER
SILVER
NICKEL

A COMPLETE TREATISE

ON THE

ELECTRO-DEPOSITION OF METALS.

COMPRISING

ELECTRO-PLATING AND GALVANOPLASTIC OPERATIONS, THE DEPOSITION OF METALS BY THE CONTACT AND IMMERSION PROCESSES, THE COLORING OF METALS, THE METHODS OF GRINDING AND POLISHING,

AS WELL AS

DESCRIPTIONS OF THE ELECTRIC ELEMENTS, DYNAMO-ELECTRIC MACHINES, THERMO-PILES, AND OF THE MATERIALS AND PROCESSES USED IN EVERY DEPARTMENT OF THE ART.

TRANSLATED FROM THE GERMAN OF

DR. GEORGE LANGBEIN,

PROPRIETOR OF A MANUFACTORY FOR CHEMICAL PRODUCTS, MACHINES, APPARATUS, AND UTENSILS FOR ELECTROPLATERS AND OF AN ELECTRO-PLATING ESTABLISHMENT, IN LEIPZIG.

WITH ADDITIONS BY

WILLIAM T. BRANNT,

EDITOR OF "THE TECHNO-CHEMICAL RECEIPT BOOK."

SECOND EDITION, REVISED AND ENLARGED.

ILLUSTRATED BY ONE HUNDRED AND THIRTY-EIGHT ENGRAVINGS.

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PREFACE TO THE SECOND AMERICAN EDITION.

THE rapid sale of the first American edition of Dr. George Langbein's work, "*Handbuch der Galvanischen Metall-Niederschlaege,*" and the constant demand for it, are the best proofs of the value and usefulness of the book.

In the second edition, which is now presented to the public, a few changes have been made in the arrangement of the text, and it has been endeavored to include all practical methods of plating metals which have become known since the publication of the first edition, as well as the most recent machinery and apparatus, so as to make the work still more acceptable and useful to the reader.

The editor is under obligations for information and electrotypes to the Hanson & Van Winkle Co., of Newark, N. J., and the Zucker & Levett Chemical Co., of New York, two well-known firms dealing in electro-platers' supplies.

The publishers have spared no expense in the proper illustration and the mechanical production of the work, and, like the first edition, it has been provided with a copious table of contents and a very full index, so as to render reference to any subject prompt and easy.

W. T. B.

PHILADELPHIA, November 14, 1893.

PREFACE TO THE FIRST AMERICAN EDITION.

THE art of the electro-deposition of metals has during recent years attained such a high degree of development, that it was felt that a comprehensive and complete treatise was needed to represent the present advanced state of this important industry. In furtherance of this object, a translation of Dr. George Langbein's work, *Vollstaendiges Handbuch der Galvanischen Metall-Niederschlaege*, is presented to the English reading public with the full confidence that it will not only fill a useful place in technical literature, but will also prove a ready book of reference and a practical guide for the workshop. In fact, it is especially intended for the practical workman, wherein he can find advice and information regarding the treatment of the objects while in the bath, as well as before and after electro-plating. The author, Dr. George Langbein, is himself a master of the art, being the proprietor of an extensive electro-plating establishment combined with a manufactory of chemical products, machinery and apparatus used in the industry.

The results yielded by the modern dynamo-electric machines, to which the great advance in the electro-plating art is largely due, are in every respect satisfactory, and the more so since the need of accurate, and at the same time handy, measuring instruments has also been supplied. With the assistance of such measuring instruments, the establishment of fixed rules regarding the current-conditions for a galvanic bath has become possible, so that good results are guaranteed from the start. While formerly the electro-plater had to determine the proper current-strength for the depositions in

an empirical manner, by time-consuming experiments, to-day, by duly observing the determined conditions and provided with well-working measuring instruments, he can at once produce beautiful and suitable deposits of the various metals.

The data referring to these current-conditions, according to measurements by Dr. Langbein, are given as completely as possible, while for the various baths, only formulæ yielding entirely reliable results have been selected. To most of the baths a brief review of their mode of action and of their advantages for certain uses is added, thus enabling the operator to select the bath most suitable for his special purpose. To the few formulæ which have not been tested, a note to that effect is in each case appended, and they are only given with due reserve.

To render the work as useful as possible, the most suitable formulæ for plating by contact and immersion, as well as the best methods for coloring the metals, and the characteristic properties of the chemicals used in the industry, are given. However, the preparation of the chemicals has been omitted, since they can be procured at much less expense from chemical works than it would be possible for the electro-plater to make them in small quantities, even if he possessed the necessary apparatus and the required knowledge of chemistry and skill in experimenting.

It is hoped that the additions made here and there by the translator, as well as the chapter on "Apparatus and Instruments," and that of "Useful Tables," added by him, may contribute to the usefulness of the treatise.

Finally, it remains only to be stated that the publishers have spared no expense in the proper illustration and the mechanical production of the book; and, as is their universal practice, have caused it to be provided with a copious table of contents, and a very full index, which will add additional value by rendering any subject in it easy and prompt of reference.

W. T. B.

PHILADELPHIA, July 1, 1891.

CONTENTS.

I.

HISTORICAL PART.

CHAPTER I.

HISTORICAL REVIEW OF ELECTRO-METALLURGY.

II.

THEORETICAL PART.

CHAPTER II.

MAGNETISM AND ELECTRICITY.

1. Magnetism.

2. Electricity.

III.

SOURCES OF CURRENT.

CHAPTER III.

GALVANIC ELEMENTS—THERMO-PILES—MAGNETO- AND DYNAMO-ELECTRIC MACHINES.

A. Galvanic Elements.

B. Thermo-Electric Piles.

C. Magneto- and Dynamo-Electric Machines.

IV.

PRACTICAL PART.

CHAPTER IV.

ARRANGEMENT OF ELECTRO-PLATING ESTABLISHMENTS IN GENERAL.

Electro-plating Arrangements in Particular.

CHAPTER V.

TREATMENT OF METALLIC ARTICLES.

A. *Mechanical Treatment.*

CHAPTER VI.

PROCESSES OF ELECTRO-DEPOSITION.

CHAPTER VII.

DEPOSITION OF NICKEL AND COBALT.

1. Nickelling.

2. Cobalting.

CHAPTER VIII.

DEPOSITION OF COPPER, BRASS, AND BRONZE.

1. Coppering.

2. Brassing (Cuivre-poli Deposit).

3. Bronzing.

CHAPTER IX.

DEPOSITION OF SILVER.

CHAPTER X.

DEPOSITION OF GOLD.

CHAPTER XI.

DEPOSITION OF PLATINUM AND PALLADIUM.

1. Deposition of Platinum.

2. Deposition of Palladium.

CHAPTER XII.

DEPOSITION OF TIN, ZINC, LEAD, AND IRON.

1. Deposition of Tin.

3. Deposition of Aluminium.

CHAPTER XIV.

GALVANOPLASTY (REPRODUCTION).

1. *Galvanoplastic Deposition in the Cell-Apparatus.*

2. *Galvanoplastic Deposition by the Battery and Dynamo-Machine.*

CHAPTER XV.

COLORING, PATINIZING, OXIDIZING, ETC., OF METALS.— LACQUERING.

CHAPTER XVI.

HYGIENIC RULES FOR THE WORKSHOP.

CHAPTER XVII.

CHEMICAL PRODUCTS AND VARIOUS APPARATUS AND INSTRUMENTS USED IN ELECTRO-PLATING.

A. Chemical Products.

I. *Acids.*

II. *Alkalies and Alkaline Earths.*

III. *Sulphur Combinations.*

IV. *Chlorine Combinations.*

V. *Cyanides.*

VI. *Carbonates.*

VII. *Sulphates and Sulphites.*

CHAPTER XVIII.

USEFUL TABLES.

ELECTRO-DEPOSITION OF METALS.

I.
HISTORICAL PART.

CHAPTER I.

HISTORICAL REVIEW OF ELECTRO-METALLURGY.

In reviewing the history of the development of electrolysis, *i. e.*, the reduction of a metal or a metallic alloy from the solution of its salts by the electric current, the simple reduction which takes place by the immersion of one metal in the solution of another, may be omitted. This mode of reduction was well known to the alchemist Zozimus, who described the reduction of copper from its solutions by means of iron, while Paracelsus speaks of coating copper and iron with silver by simple immersion in a solution of silver.

Before the discovery, in 1789, of contact-electricity by Luigi Galvani, there was nothing like a scientific reduction of metal by electricity; and only in 1799 did Alexander Volta, of Pavia, succeed in finding the true causes of Galvani's discovery. Galvani observed while dissecting a frog on a table, whereon stood an electric machine, that the limbs suddenly became convulsed by one of his pupils touching the crural nerve with the dissecting-knife at the instant of taking a spark from the conductor of the machine. The experiment was repeated several times, and it was found to answer in all cases when a metallic conductor was connected with the nerve, but not otherwise. He observed that muscular contractions were produced by forming a connection between two different metals, one of which was applied

to the nerve, and the other to the muscles of the leg. Similar phenomena having been found to arise when the leg of the frog was connected with the electric machine, it could scarcely be doubted that in both cases the muscular contractions were produced by the same agent. From a course of experiments, Galvani drew the erroneous inference that these muscular contractions were caused by a fluid having its seat in the nerves, which through the metallic connections flowed over upon the muscles. Everywhere, in Germany, England, and France, eminent scientists hastened to repeat Galvani's experiments in the hope of discovering in the organism a fluid which they considered the vital principle; but it was reserved to Volta to throw light upon the prevailing darkness. In his repeated experiments this eminent philosopher observed that one circumstance had been entirely overlooked, namely, that in order to produce strong muscular contractions in the frog-leg experiment it was absolutely necessary for the metallic connection to consist of two different metals coming in contact with each other. From this he drew the inference that the agent producing the muscular contractions was not a nerve-fluid, but was developed by the contact of dissimilar metals, and identical with the electricity of the electric machine.

This discovery led to the construction of what is known as the *pile of Volta*, or the *voltaic pile*. The same philosopher found that the development of electricity could be increased by building up in regular order a pile of pairs of plates of dissimilar metals, each pair being separated on either side from the adjacent pairs by pieces of moistened card-board or felt. On account of various defects of the voltaic pile, Cruikshank soon afterwards devised his well-known *trough battery*, which consisted of square plates of copper and zinc soldered together, and so arranged and fastened in parallel order in a wooden box, that between each pair of plates a sort of trough was formed, which was filled with acidulated water.

Nicholson and Carlisle, on May 2, 1800, first decomposed water into hydrogen and oxygen by electrolysis; and, in 1801, Wollaston remarked that if a piece of silver in connection with a more positive metal, for instance, zinc, be put into a solution of

copper, the silver will be coated over with copper, which coating will stand the operation of burnishing.

Cruikshank, in 1803, investigated the behavior of solutions of nitrate of silver, sulphate of copper, acetate of lead, and several other metallic salts, towards the galvanic current, and found that the metals were so completely reduced from their solutions by the current as to suggest to him the analysis of minerals by means of the voltaic current.

To Brugnatelli we owe the first practical results in electro-gilding. In 1805, he gilded two silver medals by connecting them by means of copper wire with the negative pole of the pile, and allowing them to dip in a solution of fulminating gold in potassium cyanide, while a piece of metal was suspended in the solution from the positive pole. He also observed that the positive plate, if it consisted of an oxidizable metal, was dissolved.

One of the greatest discoveries connected with the subject, however, is that of Sir Humphry Davy, made October 6, 1807, when, by the decomposition of the alkalies by means of the electric current, he discovered the metals potassium and sodium.

Prof. Oersted, of Copenhagen, in 1820, found that the magnetic needle is deflected from its direction by the electric current. It was known long before this that powerful electric discharges affect the magnetic needle; it had, for instance, been observed that the needle of a ship's compass struck by lightning had lost its property of indicating the North Pole, and several physicists, among them Franklin, had succeeded in producing the same phenomena by heavy discharges of the electrical machine, but they were satisfied with the supposition that the electric current acted mechanically, like the blow of a hammer. Oersted first perceived that electricity must be in a state of motion in order to act upon magnetism. This led to the construction of the galvanoscope or galvanometer, an instrument which indicates whether the elements or other source of current furnish a current or not, and by which the intensity of the source of current may also to a certain degree be recognized.

Ohm, in 1827, discovered the law named after him, that *the strength of a continuous current is directly proportional to the difference of potential or electro-motive force in the circuit,* and *inversely*

proportional to the resistance of the circuit. This law will be more fully discussed in the theoretical part.

Ohm's discovery was succeeded, in 1831, by the important discovery of *electric induction* by Faraday. By induction is understood the production of an electric current in a closed circuit which is in the immediate neighborhood of a current-carrying wire. Faraday further found that the current induced in the neighboring wire is not constant, because, after a few oscillations the magnetic needle returned to the position occupied by it before a current was passed through the current-carrying wire; whilst when the current was broken the needle deflected in the opposite direction.

In the year following the discovery of Faraday, Pixii, of Paris, constructed the *first electro-magnetic induction machine.*

Faraday's electrolytic law of the proportionality of the current-strength and its chemical action, and that the quantities of the various substances which are reduced from their combinations by the same current are proportional to their chemical equivalents, was laid down and proved in 1833, and upon this Faraday based the measurement of the current-strength by chemical deposition, as, for instance, that of water, in the voltameter.

Of the practical electro-chemical discoveries there remain to be mentioned the production of iridescent colors, in 1826, by Nobili, and the production of the amalgams of potassium and sodium, in 1835, by Bird.

The actual galvanoplastic process, however, dates from the year 1838. In the spring of 1838, Prof. Jacoby announced to the Academy of Sciences of St. Petersburg, a description of his discovery of the utility of galvanic electricity as a means of reproducing objects of metal. Hence Jacoby must be considered the father of galvanoplasty in as far as he was the first to utilize and give practical form to the discoveries made up to that time. Though Jacoby's process was published in the English periodical, "The Athenæum," of May 4, 1839, Mr. T. Spencer, who read a paper on the same subject, Sept. 13, 1839, before the Liverpool Polytechnic Society, claimed priority of invention, as was also done by Mr. C. J. Jordan, who, in May 22, 1839, sent a letter to

the "London Mechanical Magazine," which was published on June 8, 1839.

From this time forward the galvanoplastic art made rapid progress, and by the skill and enterprise of such men as the Elkingtons, of Birmingham, and De Ruolz, of Paris, it was speedily added to the industrial arts.

Though copies of a metallic object by means of galvanoplasty could now be made, the employment of the process was restricted to metallic objects of a form suitable for the purpose, until, in 1840, Murray succeeded in making non-metallic surfaces conductive by the application of graphite (black lead, plumbago), which rendered the production of galvanoplastic copies of wood-cuts, plaster-of-Paris casts, etc., possible.

Dr. Montgomery, in 1843, sent to England samples of gutta-percha, which was soon found to be a suitable material for the production of negatives of the original models to be reproduced by galvanoplasty.

Though it was now understood how to produce heavy deposits of copper, those of gold and silver could only be obtained in very thin layers. Scheele's observations on the solubility of the cyanide combinations of gold and silver in potassium cyanide, led Wright, a co-worker of the Elkingtons, to employ, in 1840, such solutions for the deposition of gold and silver, and it was found that deposits produced from these solutions could be developed to any desired thickness. The use of solutions of metallic cyanides in potassium cyanide prevails at the present time, and the results obtained thereby have not been surpassed.

From the same year also dates the patent for the deposition of nickel from solution of nitrate of nickel, without, however, attracting any special attention, which may have been chiefly due to the fact that the deposition of nickel from its nitrate solution is the most imperfect and the least suitable for the practice.

To Mr. Alfred Smee we owe many discoveries in the deposition of antimony, platinum, gold, silver, iron, lead, copper, and zinc. In publishing his experiments, in 1841, he originated the very appropriate term "electro-metallurgy" for the process of working in metals by means of electrolysis.

Prof. Bœttger, in 1842, pointed out that dense and lustrous

depositions of nickel could be obtained from its double salt, sulphate of nickel with sulphate of ammonium, as well as from ammoniacal solution of sulphate of nickel; and that such deposits, on account of their slight oxidability, great hardness, and elegant appearance were capable of many applications. Bœttger's statements also fell into oblivion, and only in later years when the execution of nickeling was practically taken up in the United States, his labors in this department were remembered in Germany. To Bœttger we are also indebted for directions for coating metals with iron, cobalt, platinum, and various patinas.

In the same year, De Ruolz first succeeded in depositing metallic alloys—for instance, brass—from the solutions of the mixed metallic salts. In 1843 the first use of thermo-electricity appears to have been made by Moses Poole, who took out a patent for the use of a thermo-electric pile instead of a volatic battery for depositing purposes.

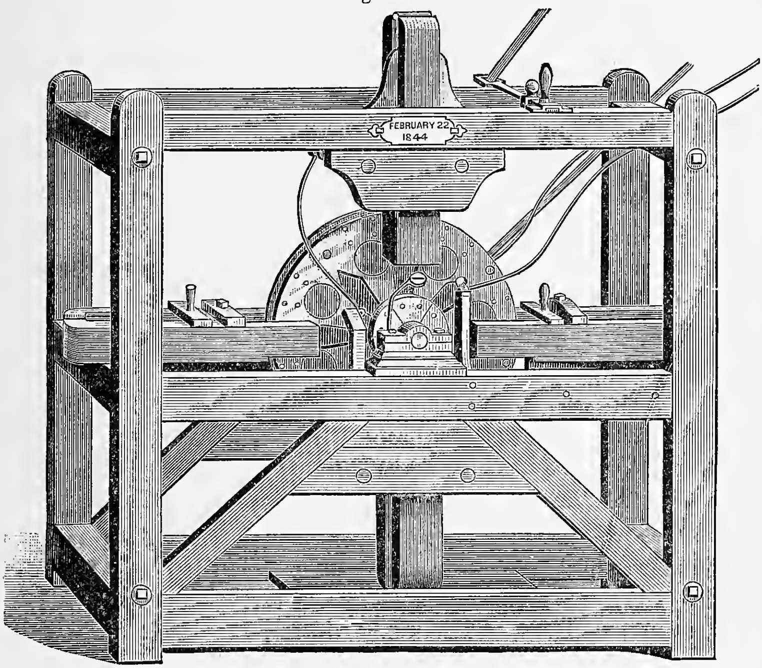
From this time forward innumerable improvements in existing processes were made; and also the first endeavors to apply Faraday's discoveries to practical purposes

The invention of depositing metals by means of a permanent current of electricity obtained from steel magnets was perfected and first successfully worked by Messrs. Prime & Son, at their large silverware works, Birmingham, England, and the original machine, constructed by Woolrych in 1844—the first magnetic machine that ever deposited silver on a practical scale—is still preserved at their works in its original position as a valuable and interesting relic. The Woolrych machine stands 5 feet high, 5 feet long, and 2½ feet wide. An illustration of this original electro-plating machine, kindly furnished us by the Hanson & Van Winkle Co. of Newark, N. J., is given in Fig. 1.

As early as 1854, Christofle & Co. endeavored to replace their batteries by magneto-electrical machines, and used the Holmes type, better known as the Alliance Machine, which, however, did not prove satisfactory ; and besides, the prices of these machines were in comparison with their efficacy exorbitant. The machine constructed by Wilde proved objectionable on account of its heating while working, and the consequent frequent interruptions in the operations.

In 1860 Dr. Antonie Pacinotti, of Pisa, suggested the use of an iron ring wound round with insulated wire, in place of the cylinder. This ring, named after its inventor, has, with more or less modifications, become typical of many machines of modern

Fig. 1.



construction. In the construction of all older machines, steel magnets had been used, and their magnetism not being constant, the effect of the machine was consequently also not constant. Furthermore, they generated alternately negative and positive currents, which, by means of commutators, had to be converted into currents of the same direction; and this, in consequence of the vigorous formation of sparks, caused the rapid wearing out of the commutators.

These defects led to the employment of continuous magnetism in the iron cores of the electro-magnets, the first machine based upon this being introduced in 1866, by Siemens, which, in 1867, was succeeded by Wheatstone's.

However, the first useful machine was introduced in 1871, by Zénobe Gramme, who in its construction made use of Pacinotti's ring. This machine was, in 1872, succeeded by Hefner-Alteneck's, of Berlin. In both machines the poles of the electro-magnet exert an inducing action only upon the outer wire wrappings of the revolving ring, the other portions being scarcely utilized, which increases the resistance and causes a useless production of heat. This defect lead to the construction of flat-ring machines, in which the cylindrical ring is replaced by one of a flat shape, and of larger diameter, thus permitting the induction of both flat sides. Such a machine was, in 1884, built by Siemens & Halske, of Berlin; and in the same year by S. Schuckert, of Nürenberg. In Schuckert's modern machines nearly three-quarters of all the wire wrappings are under the inducing influence of both of the large pole shoes of the electro-magnets.

Of other constructions of dynamo-electrical machines may be mentioned Mather's, Elmore's, Fein's, Möhring's, Krottlinger's, and Lahmeyer's, the latter especially being at the present time much employed in Germany for electro-plating purposes. In this country Weston's machine and the dynamos manufactured by the Hanson & Van Winkle Co., of Newark, N. J., the Zucker & Levett Chemical Co., of New York, and others are largely used for electro-plating purposes.

For the sake of completeness, there may be mentioned the investigators and practitioners who during the last twenty years have contributed much to the improvement of the electro-chemical processes and the perfection of galvanoplasty. Besides those already named, they are: Elkington, Becquerel, Heeren, Roseleur, Elsner, von Leuchtenberg, Meidinger, Weil, Goode, Christofle, Klein, von Kress, Thompson, Adams, Giaffe, and others.

II.

THEORETICAL PART.

CHAPTER II.

MAGNETISM AND ELECTRICITY.

1. Magnetism.

For the better understanding of the electrolytic laws it will be necessary to commence with the phenomena presented by magnetism, and to consider them more closely.

A particular species of iron ore is remarkable for its property of attracting small pieces of iron and causing them to adhere to its surface. This iron ore is a combination of ferric oxide with ferrous oxide (Fe_3O_4), and is called loadstone or magnetic iron ore. Its properties were known to the ancients, who called it magnesian stone after Magnesia, a city in Thessaly, in the neighborhood of which it was found. If a natural loadstone be rubbed over a bar of steel, its characteristic properties will be communicated to the bar, which will then be found to attract iron filings like the loadstone itself. The bar of steel thus treated is said to be magnetized, or to constitute an artificial magnet. The artificial magnets thus produced may be straight, in the shape of a horseshoe, or annular; but no matter what their form, the attractive force will appear to be greatest at two points situated near the extremities of the bar, and least of all towards the middle. The points of the magnet showing the greatest attractive force are called the *magnetic poles,* whilst the line between them, possessing little or no attractive force, is termed the *neutral line* or *neutral zone.* In a closed magnet the poles are situated on the ends of one and the same diameter, while the neutral zones are located on the ends of a diameter standing perpendicular to the first.

When a magnetized bar or natural magnet is suspended at its centre in any convenient manner, so as to be free to move in a horizontal plane, it is always found to assume a particular direction with regard to the earth, one end pointing nearly north and the other nearly south. If the bar be removed from this position it will tend to reassume it, and, after a few oscillations, settle at rest as before. The direction of the magnetic bar, *i. e.*, that of its longitudinal axis, is called the *magnetic meridian*, while the pole pointing towards the north is usually distinguished as the *north pole* of the bar, and that which points southward as the *south pole.*

A magnet, either natural or artificial, of symmetrical form, suspended in the presence of a second magnet, serves to exhibit certain phenomena of attraction and repulsion, which deserve particular attention. When a north pole is presented to a south pole, or a south pole to a north, attraction ensues between them; the ends of the bar approach each other, and, if permitted, adhere with considerable force; when, on the other hand, a north pole is brought near a second north pole, or a south pole near another south pole, mutual repulsion is observed, and the ends of the bar recede from each other as far as possible. *Poles of an opposite name attract, and poles of a similar name repel each other.*

According to the theory or hypothesis proposed by Ampère magnetism is caused by the presence of electric currents in the ultimate particles of matter. This theory assumes—

1. That the ultimate particles of all magnetizable bodies have closed electric circuits in which electric currents are continually flowing.

2. That in an unmagnetized body these circuits neutralize one another, because they have different directions.

3. That the act of magnetization consists in such a polarization of the particles as will cause these currents to flow in the one and the same direction, *magnectic saturation* being reached when all the separate circuits are parallel to one another.

4. That *coercive force* is due to the resistance these circuits offer to a change in the direction of their planes.

Guided by these considerations Ampère produced a coil of wire, called a *solenoid*, which is the equivalent of the magnetizing circuit assumed by his theory. It therefore follows that an electric cur-

rent sent through a coil of insulated wire surrounding a rod or bar of soft iron, or other readily magnetizable material, will make the same a magnet. A magnet so produced is called an electro-magnet; the magnetizing coil is called a helix, or solenoid. The polarity of the magnet depends on the direction of the current, or on the direction of winding of the helix or solenoid. The improbability of an electric current continually flowing in a circuit without the expenditure of energy, has led many scientific men to reject Ampère's theory of magnetism.

If an iron or steel needle be suspended free in the neighborhood of a magnet, it assumes a determined direction according to its greater or smaller distance from the poles or from the neutral zone; however, before the needle assumes this direction it swings quickly, with a shorter stroke, or slowly with a longer stroke, according to the greater or smaller attractive force exerted upon it. The space within which the magnetic action of a magnet is exercised is called the *magnetic field*, and the magnetic as well as the electric attractions and repulsions are, according to Coulomb, as the densities of the fluids acting upon each other and inversely as the square of their distance.

2. Electricity.

In an ordinary state solid bodies exhibit no attractive effect upon small light particles, such as strips of paper, balls of elder-pith, etc; but by rubbing many solid bodies with a piece of dry cloth or fur they acquire the property of attracting such light bodies as mentioned above. The cause of this phenomenon is called *electricity*, and the bodies which possess this property of becoming electric by friction are termed *idio-electrics*, and those which do not appear to possess it, *non-electrics*. Gray, in 1727, found that all non-electric bodies conduct electricity, and hence are conductors, while those which become electric by friction are non-conductors of electricity. Strictly speaking, there are no non-conductors, because the resins, silk, glass, etc., conduct electricity, though only very slightly. It is therefore better to distinguish *good* and *bad* conductors. To test whether a body belongs to the idio-electrics, the so-called electroscope is used, which in its

simplest form consists of a glass rod mounted on a stand, and bent at the top into a hook, from which hangs by a silken thread or hair a pith ball. If, on bringing the rubbed body near the pith ball, the latter is attracted, the body is electric, whilst if the ball is not attracted, the body is either non-electric or its electricity is too slight to produce an attractive effect.

From the following experiments it was found that there exist *two* kinds of electricity: When a rubbed rod of glass or shellac is brought near the ball of elder-pith suspended to a silk thread, the ball is attracted, touches the rod, adheres for a few moments and is then repulsed. This repulsion is due to the fact that the ball by coming in contact with the rod becomes itself electric, and its electricity must first be withdrawn by touching with the hand before it can again be attracted by the rod. By now taking two such balls, one of which has been made electric by touching with a glass rod, which had been rubbed with silk, and the other by touching with a shellac rod rubbed with cloth, it will be observed that the ball, which is repulsed by the glass rod, is attracted by the shellac rod and *vice versa*. These two kinds of electricity are called *vitreous* or *positive*, and *resinous* or *negative* electricty, and it has been found that *electricities of a similar name attract*, and *electricities of an opposite name repel, each other*.

For want of a concrete knowledge of the electric agent which produces the electric phenomena, various theories or hypotheses have been advanced to explain these phenomena and the action of the electric forces. Only two of the best known theories or hypotheses shall here be mentioned.

Double fluid hypothesis of electricity. By this hypothesis it is endeavored to explain the causes of electric phenomena by the assumption of the existence of two different electric fluids.

The double fluid hypothesis assumes :—

1. That the phenomena of electricity are due to two tenuous and imponderable fluids, the positive and the negative.

2. That the particles of the positive fluid repel one another, as do also the particles of the negative fluid; but that the particles of the positive fluid attract the particles of the negative, and *vice versa*.

3. That the two fluids are strongly attracted by matter, and when present in it produce electrification.

4. That the two fluids attract one another and unite, thus masking the properties of each.

5. That the act of friction separates these fluids, one going to the rubber and the other to the thing rubbed.

Single-fluid hypothesis of electricity. By this hypothesis it is endeavored to explain the cause of electric phenomena by the assumption of the existence of a single electric fluid.

The single fluid hypothesis assumes :—

1. That the phenomena of electricity are due to the presence of a single, tenuous, imponderable fluid.

2. That the particles of this fluid mutually repel one another, but are attracted by all matter.

3. That every substance possesses a definite capacity for holding the assumed electric fluid, and that when this capacity is just satisfied, no effects of electrification are manifest.

4. That when the body has less than this quantity present, it becomes *negatively excited*, and when it has more, *positively excited.*

5. That the act of friction causes a redistribution of the fluid, part of it going to one of the bodies, giving it a surplus, thus positively electrifying it, and leaving the other with a deficit, thus negatively electrifying it.

According to Coulomb, *the electric attractions and repulsions are as the densities of the fluids acting upon each other, and inversely as the square of the distance.*

However, a current of electricity is created not only by friction, but also by the contact of various metals. In the same manner as the copper and iron in Galvani's experiments with the frog leg, other metals and conductors of electricity also become electric by contact, the electric charges being, however, stronger or weaker, according to the nature of the metals. If zinc be brought in contact with platinum, it becomes more strongly positively electric than when in contact with copper; whilst, however, copper in contact with zinc is negatively excited, in contact with platinum it becomes positively electric. By now arranging the metals in a series, so that each preceding metal becomes positively electric in contact with the succeeding, a *series of electro-*

motive force or tension is obtained, in which the metals or conductors of electricity stand as follows :—

+ Zinc, cadmium, tin, iron, lead, copper, nickel,
Silver, antimony, gold, platinum, carbon —.

While two metals of the series of electro-motive force or tension touching each other become electrically excited in such a manner that one becomes positively and the other negatively electric, an exchange of the opposite electricities takes place by introducing a conducting fluid between the metals. Thus, if a plate of zinc and a plate of copper connected by a metallic wire are immersed in a conducting fluid, for instance, dilute sulphuric acid, the electricity of the positive zinc passes through the fluid to the negative copper, and returns through the wire—the *closing circuit*—to the zinc. However, in the same degree with which the electricities equalize themselves, new quantities of them are constantly formed on the points of contact of the metals with the conducting fluid; and, hence, the flow of electricity is continuous. This electric current generated by the contact of metals and fluids is called the *galvanic current;* or, since it is generated by the intervention of fluid conductors, *hydro-electric* current. A combination of conductors which yields such a galvanic current, is called a *galvanic element*, or a *galvanic chain.*

It would here be the place to discuss the various galvanic elements, but it is thought better to describe them in a separate chapter, and first to explain the laws and the actions of the galvanic current.

Electrical potential.—The property of electricity corresponding to *head* or *pressure*, as applied in speaking of gas or water-power, is termed the *electrical potential.* Two bodies have the same electrical potential when, connected by a metallic wire, they develop no electricity.

Electro-motive force.—If, however, two bodies connected by a metallic wire possess unequal electrical potentials, a movement of the electricity takes place, and the force which produces this movement or current is called the electro-motive force or tension. It, therefore, corresponds to the difference of the potentials; and

the magnitude of this difference of the potentials is the measure for the electro-motive force.

Resistance.—All conductors offer a certain amount of resistance to the forward movement of the electric current. By connecting, for instance, two bodies charged with electricity and possessing a difference of potentials, by a metallic conductor, a certain time is required for the compensation of the difference of potentials, or, in other words, before the electrical equilibrium is established. By now keeping the difference of potentials constant, the quantity of electricity which passes through the closing conductor—the closing circuit—depends on the resistance which the latter offers to the passage of the current.

The resistance of a conductor is proportional to its length and inversely to its cross-section and its conducting capacity; i. e., the longer the conducting circuit the greater the resistance, and the greater its cross-sections the smaller the resistance. Wires of small diameter will, therefore, offer greater resistance to the current than those with larger diameter, and wires with good conducting capacity will produce less resistance than those with poor conducting capacity. According to Lazere Weiler, the conductivity of metals is as follows:—

Name of metal.	Mean conductivity.	Alloys, etc.	Mean conductivity.
Silver	100.0	Cu with 4 per cent. Si,	75.0
Copper	100.0	Cu " 12 " Si,	54.7
Gold	80.6	Cu " 9 " P,	4.9
Aluminium	55.1	Cu " 10 " Pb,	30.0
Zinc	30 2	Cu " 10 " Al,	12.6
Platinum	16.7	Cu " 10 " As,	9.1
Iron	16.4	Cu " 20 " Sn,	8.4
Tin	15.2	Cu " 35 " Zn,	21.1
Lead	8.8	Cu " 50 " Ag,	86.6
Nickel	7.9	Au " 50 " Ag,	16.1
Antimony	4.2	Sn " 12 " Na,	46.9

Quantity of current. Ohm's law.—The quantity of electricity or, in other words, the current-strength, which an element furnishes at a determined extreme point, depends on the strength of the electro-motive force which impels the current, as well as on the resistance which the conductor offers to the current. In

the preceding it has been seen that the electro-motive force corresponds to the difference of the potentials of two conductors connected by a metallic wire; the greater this difference is, the greater the energy with which the compensation of the electricities takes place. It has also been explained that the resistance increases in proportion to the length, and decreases with the increase in the cross-section of the conductor. Upon these relations Ohm's law is based, and in its completeness it may be summed up as follows: *The quantity of electricity or the strength (intensity) of current is directly proportional to the sum of the electro-motive forces of the exciting elements, and is inversely proportional to the sum of the resistances of its closing circuit; however, the resistance of each part of the closing circuit is proportional to its length and inversely proportional to its cross-section.* Now, if S indicates the strength of current, E the sum of the electro-motive forces, and L the total resistance, then the strength of current S is—

$$S = \frac{E}{L}.$$

The total resistance L is, however, composed of two different resistances, namely, of the so-called *essential* or *internal* resistance, which expresses the resistance of the substances in the elements themselves, and of the *non-essential* or *external* resistance of the closing circuit. If, therefore, the internal resistance $= R$ and the external resistance $= r$, the total resistance will be $L = R + r$, and the formula given above is changed to

$$S = \frac{E}{R + r}.$$

Let us now examine the useful applications which result from Ohm's law, to the coupling of the elements, they being of great importance to the practical electro-plater. According to the above formula, which expresses the total performance of a battery, the strength of current of a single element is, if s indicates its current strength, e the electro-motive force, R the essential or internal resistance, and r the resistance in the closing circuit,

$$s = \frac{e}{R + r}.$$

By now uniting several such elements, let us say n elements, to a column, the electro-motive force of the latter has become

$n+e=n\,e$, and the internal resistance $n\,r$; with the same closing circuit as that of the single element, r will not increase, hence the strength of current of these n elements must be written—

$$s=\frac{n\,e}{n\,R+r}.$$

It is now clear that when a determined closing circuit of the resistance r is given that the strength of current cannot be indefinitely augmented by increasing the number of n elements; because, though the electro-motive force, by the augmentation of n elements, increases by so many n, the internal resistance R also grows, so that finally the value r, which remains constant, disappears, contrary to the resistance R, which increases n times. Hence, the strength of current constantly approaches more the limit of value—

$$\frac{n\,e}{n\,R}=\frac{e}{R}.$$

On the other hand, the effect can neither be increased by enlarging the area of the pair of plates nor by decreasing the resistance of the fluid in a given number of elements. Because, when r, the external resistance, is sufficiently large so that the internal resistance, $n\,R$, may be neglected, the intensity always approaches more the value $\frac{e}{r}$.

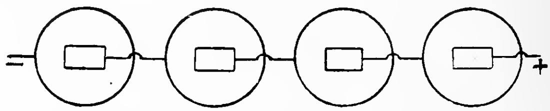
Hence, it follows *that the augmentation of the area of the exciting pair of plates produces an increase in the current-strength only when the external resistance in the closing circuit is small in proportion to the internal resistance of the battery.*

If we now apply the results of the above explanations to practice, we find that the elements may be coupled in various ways according to requirement.

1. If, for instance, four Bunsen elements (carbon-zinc) are coupled *one after another* in such a manner that the zinc of one element is connected with the carbon of the next, and so on (Fig. 2), the current passes four times in succession through an equally large layer of fluid, in consequence of which the internal resistance, 4 R, is four times greater than that of a single element, while the resistance of the closing circuit, r, remains the same.

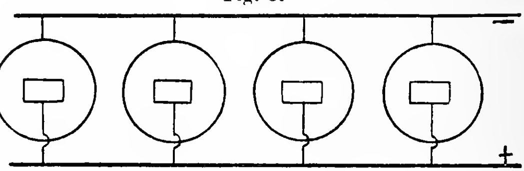
Hence, while the current-strength is thereby not increased, the electro-motive force is, and for this reason this mode of coupling is called the *union* or *coupling of the elements for electro-motive force or tension.*

Fig. 2.



2. By connecting four elements *alongside of each other, i. e.,* all the zinc plates and all the carbon plates one with another (Fig. 3),

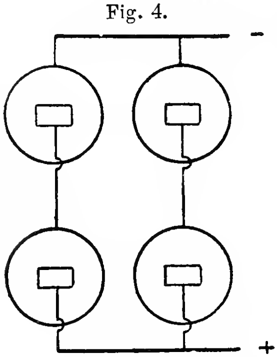
Fig. 3.



the current simultaneously passes through the same layer of fluid in four places; the internal resistance of the battery is therefore the same as that of a single element, and since the area of the plates is four times larger than that of a single element, the quantity of current is augmented by this mode of coupling. This is called *coupling for quantity of current.*

3. Two elements may, however, be connected for electro-motive force or tension, and several such groups coupled alongside of each other as shown in Fig. 4, whereby, according to what has above been said, the electro-motive force as well as the current-strength is augmented. This mode of connection is called *mixed coupling.*

Fig. 4.



According to the resistance of the bath as well as of the exterior closing circuit, and the surfaces to be plated, the electro-plater may couple his elements in either way, and in speaking later on

of the elements the various modes of coupling will be further discussed. We will here only mention the proposition deduced from Ohm's law that *a number of galvanic elements yield the maximum of intensity of current when they are so arranged that the internal resistance of the battery is equal to the resistance in the closing circuit.* Hence, when operating with baths of good conductivity and slight resistance, for instance, acid copper baths, silver cyanide baths, etc., with a slight distance between the anodes and the objects and with a large anode-surface, it will be advantageous to couple the elements *alongside of each other for quantity;* however, for baths with greater resistance and with a greater distance of the anodes from the objects, and with a smaller anode surface, it is best to couple, the elements *one after the other for electro-motive force or tension.*

The effects of the electric current are thermal, physiological, electro-magnetic, inductive, and chemical; however, for our purposes, only the last three need be discussed.

Electro-magnetism.

If a wire conveying the electric current be brought near a magnetic needle, the latter will immediately be deflected from its direction, no matter whether the wire conveying the current be placed alongside, above, or beneath the magnetic needle. The direction which the needle will assume when placed in any particular position to the conducting wire may be determined by the following rule: *Let the current be supposed to pass through a watch from the face to the back: the motion of the north pole will be in the direction of the hands. Or, let the observer imagine himself swimming in the direction of the current with his face towards the needle: the north pole of the needle will then be deflected towards his left hand.*

When the needle is subjected to the action of two currents in opposite directions, the one above and the other below, they will obviously concur in their effects. The same thing happens when the wire carrying the current is bent upon itself and the needle placed between the two portions; and since every time the bending is repeated a fresh portion of the current is made to act in

the same manner upon the needle, it is easy to see how a current, too feeble to produce any effect when a simple straight wire is employed, may be made by this contrivance to exhibit a powerful action on the magnet. It is on this principle that instruments called *galvanoscopes*, *galvanometers*, or *multipliers* are constructed. They serve not only to indicate the existence of electrical currents, but also to show by the effects upon the needle the direction in which they are moving. The delicacy of the instrument has been increased by Nobili through the use of a very long coil of wire, and by the addition of a second needle. This instrument is known as the *astatic galvanometer*. The two needles are of equal size and magnetized as nearly as possible to the same extent; they are then immovably fixed together parallel and with their poles opposed, and hung by a long fibre of untwisted silk, with the lower needle in the coil and the upper one above it. The advantage thus gained is twofold: the system is *astatic*, unaffected, or nearly so, by the magnetism of the earth; and the needles being both acted upon in the same manner by the current, are urged with much greater force than one alone would be, all the actions of every part of the coil being strictly concurrent. A divided circle is placed below the upper needle, by which the angular motion can be measured, and the whole is inclosed in glass, to shield the needles from the agitation of the air.

The deflection of the magnetic needle by the electric current has led to the construction of instruments which allow of the intensity of the current being measured by the magnitude of the deflection. Such instruments are, for instance, the *tangent galvanometer*, the *sine galvanometer*, etc., but they are almost exclusively used for scientific measurements, while for the determination of the intensity of current for electro-plating purposes other instruments are employed, which will be described later on. However, the electric current exerts not only a reflecting action on magnetic needles, but is also capable of producing a magnetizing effect on iron and steel. If a bar of iron be surrounded by a coil of wire, covered with silk or cotton for the purpose of insulation, it becomes magnetic so long as the current is conducted through the coil. Such iron bars converted into temporary magnets by the action of the current are called *electro-magnets*, and

they will be the more highly magnetic the greater the number of turns of the coil, and the more intense is the current passing through the turns.

However, not only the iron bar, around which the current circulates, becomes magnetic, but also a conducting wire through which passes a strong current. By suspending a circular conducting wire so that it is free to move around its vertical axis, its direction is affected by the magnetism of the earth, and it will take up a position so that its plane stands at a right angle to the plane of the magnetic meridian; by now conducting the current through a wire having the form of a long helix, a so-called *solenoid,* the wire will, in a like manner, place itself with the turns of the helix at right angles to the plane of the magnetic meridian, or, in other words, the axis of the solenoid will lie in the magnetic meridian.

In the same manner as an electrified conducting wire acts upon a magnet, two electrified wires exert an attracting and repelling influence on each other, the general law of the action being that, *electric currents moving in parallel lines attract one another, if they move in the same direction, and repel one another if they move in opposite directions.*

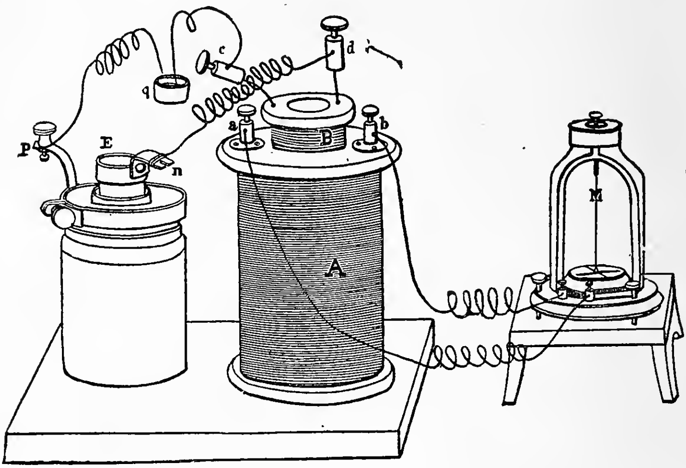
Induction.

By induction is understood the production of an electric current in a closed circuit which is in the immediate neighborhood of a current-carrying wire.

Suppose we have two insulated copper wire spirals, A and B (Fig. 5), B being of smaller diameter and inserted in A. When the two ends of B are connected with the poles of a battery a current is formed in A the moment the current of B is closed. This current is recorded by the deflection of the magnetic needle of a multiplier, M, which is connected with the ends of A, the deflection of the needle showing that the current produced in A by the current in B moves in an opposite direction. The current in A, however, is not lasting, because, after a few oscillations, the magnetic needle of the multiplier returns to its previous position and remains there no matter how long the current may pass

through *B*. If, however, the current in *B* be interrupted, the magnetic needle swings to the opposite direction, thus indicating the formation of a current in *A*, which passes through it in the same direction as the interrupted current in *B*.

Fig. 5.



The current causing this phenomenon is called the *primary* or *inductive* current, and that produced by it in the closed circuit the *secondary* or *induced* current. From what has been above said, it is clear that *an electric current at the moment of its formation induces in a neighboring closed circuit a current of opposite direction, but when interrupted, a current of the same direction.*

In the same manner as closing and opening the inductive current, its sudden augmentation also effects the induction of a current of opposite direction in a neighboring wire, while its sudden weakening induces a current of the same direction; the same effect being also produced by bringing the inductive wire closer to, or removing it further from, the neighboring wire. The induced currents being alternately formed by opening and closing the circuit, and they showing different directions, the term *alternating currents* has been applied to them.

If the turns of the spirals are very close together, each turn induces the other, the so-called *extra currents* being thereby formed.

The induced currents follow Ohm's law the same as the induc-

tive current. A long inducing wire with a small cross-section offers greater resistance than a short wire with a larger cross-section, and consequently in the first case the current will possess slighter intensity and higher tension, and in the other greater intensity and less tension.

In the same manner as an electrified wire induces a current in a neighboring wire, a magnet or electro-magnet also produces induced currents in a coil of wire surrounding it. These currents act in the same manner as those produced by other means, and by taking into consideration Ohm's law, currents of great and slight intensity can be produced at will, as will be seen in speaking of the dynamo-electric machines, the construction of which is based upon the principle of induction.

Chemical actions of the electrical current—Electrolysis.

An electric current on being conducted through a fluid effects the reduction of its constituents. By cutting, for instance, the conductor of an electric current, and introducing the two wire ends thereby formed into water acidulated with dilute sulphuric acid, the water, provided the current is strong enough, is decomposed into its constituents, hydrogen and oxygen, the former separating in the form of gas on the negative pole and the latter on the positive. If such a decomposition does not take place, the fluid does not conduct the current. Pure water by itself is a bad conductor, and to make its decomposition possible it has to be made conductive by acidulation with dilute sulphuric acid. When a chemical composition is decomposed by the current, the constituent forming the basis of the combination separates on the negative pole, and that constituting the acid on the positive; hence metals and hydrogen are liberated on the negative, and acids and oxygen on the positive pole. To Faraday is due the discovery of the chemical actions of the current and the exposition of the laws governing the separation of the constituents. He adopted the term *electrolysis* for the electrical separation of chemical combinations, and *electrolyte* for the fluids subjected to electrical decomposition. To the poles or plates leading the current into and out of the electrolyte he applied the term *electrodes*,

the positive pole being the *anode*, and the negative pole the *cathode*. The elements of the electrolyzed liquid, which are liberated by the action of the current, are termed *ions*, those set free on the anode or positive electrode being termed *anions*, and those at the cathode or negative anode *cations*. Thus, when acidulated water is electrolyzed, two ions are evolved, namely, oxygen and hydrogen, the former at the positive and the latter at the negative electrode.

It is absolutely necessary for the electrolyte to be in a fluid state, though it does not matter whether the fluid state is produced by solution or fusion.

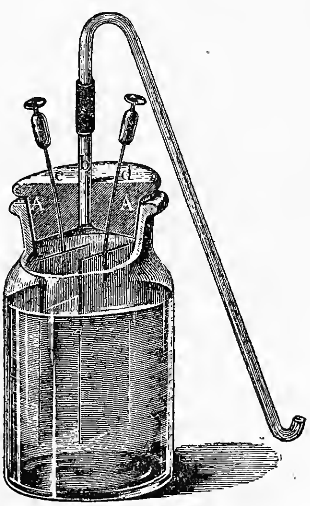
We know no more of the actual cause of the chemical action of electricity than of its nature and origin. According to Clausius's theory, matter is composed of minute particles called molecules, which, though mechanically indivisible, are chemically divisible; the constituent parts of the molecules which are no further chemically divisible are called *atoms*. Clausius supposes that the molecules are in constant motion; that in solid bodies they move around determined positions of equilibrium, while in fluids even apparently tranquil they move from one place to another, constantly revolving and pushing against one another without being subjected to a return to their original positions. In pushing against one another the molecules are decomposed into the atoms of which they are composed; those atoms, however, which have become electro-negative under the influence of the current endeavor to reach the anode, while those which have become electro-positive move towards the cathode. But in doing this they meet atoms of opposite polarity with which they reunite to a molecule until they are again liberated by this molecule pushing against another, when they move further towards the anode. Arriving at the electrodes, they find no more atoms of opposite polarity with which they might unite to a molecule; both atoms, therefore, remain free on the electrodes, while the electrolyte between the two electrodes suffers no perceptible change. The atoms are, therefore, to be considered as ions. However, in order that the ions may be attracted by the electrodes, a current of determined electro-motive force is required; as otherwise, though the electrolyte may conduct the current, the atoms attract one another more

vigorously than they are attracted by the electrode and again form molecules. To this mutual attraction of the atoms of opposite polarity is due the resistance of the electrolyte to the transmission of the current, and also the formation of a current of an opposite direction to that of the primary current, which is called the *counter* or *polarizing current.* This counter current, which is so effectually utilized with accumulators (secondary batteries), is the worst enemy of the electro-plater, and to overcome it very strong currents have frequently to be used, as will be shown, for instance, in nickeling sheet zinc.

Faraday is also the discoverer of the following *electrolytic laws:*

First law. The quantity of substance separated within a determined time by the current is directly proportional to the strength of the current. By conducting the current through a voltameter (Fig. 6), *i. e.*, a closed decomposing cell provided with two platinum electrodes, which are in contact with the poles of the element, and dip into acidulated water, oxygen evolves on the positive electrode and hydrogen on the negative. The gas mixture (oxyhydrogen gas) is conducted through a bent tube inserted air-tight in the stopper of the cell, into graduated tubes, in such a manner that the gas enters the tubes under water; the escaping mixture of gas rises in the form of bubbles into the upper part of the tube, and the volume of gas there collected in a determined time can be readily read off.

Fig. 6.



Now, if a current of determined strength has produced a determined quantity of oxyhydrogen gas in the voltameter, a current twice as strong will, according to Faraday's law, produce in the same time double the volume of gas, from which further results the fact that for the decomposition of a determined quantity of any body, a con-

stant quantity of current is always required, to which the term *electrical equivalent* might be applied.

Second law. If the same current acts upon a series of different solutions, the weights of the elements separated at the same time in each solution are proportional to their chemical equivalents. If, for instance, the same current be conducted through three decomposing cells, one of which contains water, the second a solution of blue vitriol, and the third a solution of nitrate of silver, for each gramme of hydrogen developed in the first cell, 31.75 grammes of copper will be separated in the second cell, and 108 grammes of silver in the third cell, because their chemical equivalents are as 1 : 31.75 : 108.

Third law. In an element, the chemical decomposition—the dissolution of zinc—is proportional to the strength of current; or, in other words, as many equivalents of zinc are dissolved in the element as equivalents of another metal are separated in an inserted electrolyte. Every electro-plater observes that the zinc cylinders of the elements are dissolved; and it is just this solution which maintains the development of the electric current. As is well known, zinc is strongly attacked and dissolved by dilute sulphuric acid; therefore a dissolution of zinc takes place before the galvanic apparatus is closed. This dissolution of zinc, independent of the production of current, is termed *local action*, and to decrease it the zinc is amalgamated by first washing it with strong soda to remove grease. Then it is dipped into a vessel of water containing $\frac{1}{10}$th of sulphuric acid; as soon as strong action takes place it is transferred to a suitable dish, mercury poured over it, and finally is rubbed till a bright silver-like film forms; then it is set up on edge to drain, and before use any globules set free are rubbed off. If local action has thus been prevented, only as much zinc will dissolve, according to this law, as is chemically equivalent to the metal separated in the decomposing cell. If, however, local action is present, the consumption of zinc is increased by the quantity corresponding to solution by local action.

Electro-chemical equivalents.—This term is applied to the weights of the various electrolytes which are decomposed in the unit of time by the electric unit. The electro-chemical equivalents are proportional to their chemical equivalents. The electro-

chemical equivalent of a body is found by multiplying its chemical equivalent by the electro-chemical equivalent of hydrogen =0.0001022.

When an electric current passes through a conductor, the latter becomes more or less heated. According to Joule's experiments, it was found that *the development of heat in the conductor is proportional to its resistance; and further, that it is proportional to the square of the strength of current.*

Hence the development of heat will be the greater the smaller the cross-section of the conductor and its conducting capacity are; and the larger the quantity of current which passes through it. For practical purposes, the conclusion derived from this is the necessity of choosing conducting wire of good conducting capacity and of sufficiently large diameter to prevent the development of heat, which in this case means loss of current.

Consumption of power in electrolysis.—Without a desire further to enter into the details of the electro-chemical theory, it may, for the sake of completeness, be mentioned that *the force required for the decomposition of an electrolytic solution is at least equal to that which, when converted into heat, corresponds to the heat developed by the separated bodies in their reunion into their original combination.*

Electric units.—The electro-motive force required for the decomposition being frequently given, as well as the intensity which the current must possess in order properly to coat a determined surface of articles with the electrolytically separated metal, the electric units serving for electric measures will be briefly given :—

To measure the physical phenomena of the current it is necessary to refer to mass, length, and duration of time, and the units adopted by the International Congress of 1881 are as follows :—

1. Unit of length, 1 centimetre.
2. Unit of time, 1 second.
3. Unit of mass, the mass of one gramme.

The term *fundamental* or C. G. S. (centimetre-gramme-second) units has been applied to this system.

Force or power (F)—Dyne.—Force which acting upon 1 gramme for a second generates a velocity of 1 centimetre per second.

Work—Erg.—Amount of work done by 1 dyne working through 1 centimetre of distance.

Quantity.—The quantity conveyed by unit current in 1 second.

Potential or electromotive force.—The difference of the electric condition between two conductors or two points of a conductor, when the transference of electricity from one to the other is proceeding at the rate of 1 erg of work per unit of electricity transferred.

Resistance.—A resistance such that with unit of difference of potential between the ends of conductor, 1 unit of current is conveyed along it.

Of the so-called practical units, which were retained by the Congresses and Conferences of 1881 and 1884, there are five: the *ohm, volt, ampère, farad,* and *coulomb.*

The *ohm* is the practical unit of resistance. It is equal to the resistance of a column of mercury 1 metre long and 1 square millimetre in cross-sectional area at 0° C., and approximately equal to the resistance of 48.5 metres of pure copper wire, 1 millimetre in diameter, at 0° C. The ohm is equal to 10^9 C. G. S. units.

The *ampère* is the practical unit of the current-strength (intensity); it is equal to $\frac{1}{10}$ of the theoretical C. G. S. unit. For practical purposes the quantity of silver precipitated in one second is taken as the representative value of an ampère, 0.0011188 gramme of silver corresponding, according to Kohlrausch, to one ampère.

The *volt* is the practical unit of the electro-motive force, and is equal to 10^8 C. G. S. units. It is approximately equal to the electro-motive force of a single Daniell's cell.

The *farad* is the practical unit of capacity equal to 10^9 C. G. S. units; the *coulomb* is the unit of quantity, *i. e.*, the volume of current equal to that of 1 ampère passing through a circuit for one second of time.

A current of 1 ampère at the pressure of 1 volt is termed a *watt;* it is a most useful unit for comparing different currents, and is really the product of volume into pressure.

The English horse-power (*H. P.*) is taken at 550 foot-pounds per second, and is thus equivalent to raising 550 pounds through one foot; or, one pound through 550 feet in a second. (The French *H. P.* is 542.48 foot-pounds per second.)

III.

SOURCES OF CURRENT.

CHAPTER III.

GALVANIC ELEMENTS—THERMO-PILES—MAGNETO- AND DYNAMO-ELECTRIC MACHINES.

THE sources of current used for electro-deposition of metals are the *galvanic elements, thermo-piles, magneto-electric machines,* and *dynamo-electric machines.*

A. *Galvanic Elements.*

It is not proposed to enter into a detailed description of all the forms of galvanic elements, because the number of such constructions is very large, while the number of those which have been successfully and permanently introduced for practical work is comparatively small.

The original form of the galvanic elements, the voltaic pile, consisting of zinc and copper plates separated from one another by moist pieces of cloth, has been already mentioned on p. 2, as well as its disadvantages which led to the construction of the so-called *trough battery.* The separate elements of this battery are square plates of copper and zinc, soldered together and parallel, fixed into water-tight grooves in the sides of a wooden trough so as to constitute water-tight partitions which are filled with acidulated water. The layer of water serves here as a substitute for the moist pieces of cloth in the voltaic pile.

In other constructions the fluid is in different vessels, each vessel containing a zinc and a copper plate which do not touch one another in the same vessel, the copper plate of the one vessel being connected with the zinc plate of the next, and so on.

In all elements with one fluid as an excitant, the current is quite strong at first, but quickly decreases for the following reasons: First, during the interruption of the current a change takes place in the fluid by the local action in the element, and then with a closed circuit the zinc with the impurities it contains forms *small voltaic piles*, the element consequently also performing a certain chemical work during the interruption of the current. As mentioned on p. 26, the local action can be reduced to a minimum by amalgamating the zinc. Such amalgamation is also a protection against the above-mentioned chemical work of the element, the bubbles of hydrogen adhering so firmly to the amalgamated homogeneous surface as to form a layer of gas around the zinc surface, which prevents its contact with the fluid.

Amalgamation may be effected in various ways. The zinc is either scoured with coarse sand moistened with dilute sulphuric or hydrochloric acid, or pickled in a vessel containing either of the dilute acids. The mercury may be either mixed with moist sand and a few drops of dilute sulphuric acid, and the zinc be amalgamated by applying the mixture by means of a wisp of straw or a piece of cloth; or the mercury may be applied by itself by means of a steel wire brush, the brush being dipped in the mercury, and what adheres quickly divided upon the zinc by brushing until the entire surface acquires a mirror-like appearance. The most convenient mode of amalgamation is to dip the zinc in a suitable solution of a mercury salt and rub with a woollen rag. A suitable solution is prepared by dissolving 10 parts by weight of mercurous nitrate in 100 parts of warm water, to which pure nitric acid is added until the milky turbidity disappears. Another solution, which is also highly recommended, is obtained by dissolving 10 parts by weight of mercuric chloride (corrosive sublimate) in 12 parts of hydrochloric acid and 100 of water. In order to preserve as much as possible the coating of mercury upon the zinc, sulphuric acid saturated with neutral mercuric sulphate is used for the elements; for which purpose frequently shake the concentrated sulphuric acid (before diluting with water) with the mercury salt.

Bouant recommends instead of the addition of mercuric sulphate, to compound the dilute sulphuric acid with 2 per cent. of

a solution obtained as follows: Boil a solution of $3\frac{1}{2}$ ozs. of nitrate of mercury in 1 quart of water, with an excess of a mixture of equal parts of mercuric sulphate and mercuric chloride, and, after cooling, filter and use the clear solution.

The third reason for the decrease of the current-strength in elements with one fluid is *polarization.* By polarization is understood the appearance in the element of a second current which, being opposite to that produced by the element, weakens the action of the latter. The cause of galvanic polarization is found in the fact that the negative pole-plate becomes coated with a layer of hydrogen, whereby according to Clausius's theory (p. 24) the attraction of the anodes for the ions is essentially weakened, while, according to another theory, the electro-negative plate, by contact with the layer of gas, becomes electro-positive towards the other, which is coated with bubbles of oxygen.

Polarization can only be entirely avoided in elements the negative pole-plate of which dips into a fluid which oxidizes the hydrogen to water, as is the case in the so-called *constant* elements with two fluids, as will be seen later on.

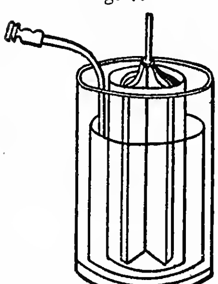
Proceeding from the conviction that rough surfaces allow the bubbles of hydrogen to pass off much more freely than smooth surfaces, Smee constructed the element named after him. It consists of a zinc plate and a platinized silver plate dipping into dilute acid. It may be formed of two zinc plates mounted with the platinized silver between them in a wooden frame, which being a very feeble conductor may carry away a minute fraction of the current, but serves to hold the metals in position, so that quite a thin sheet of silver may be employed without fear of its bending out of shape and making a short circuit. The platinizing is effected by hanging the silver plates in a vessel filled with acidulated water, adding some chloride of platinum and placing the vessel in a porous clay cell filled with acidulated water and containing a piece of zinc, the latter being connected with the silver plates by copper wire. The platinizing obtained in this manner is a black powder which roughens the surfaces, in consequence of which the bubbles of hydrogen become readily detached and the polarization is less than with silver plates not platinized. The use of electrolytically prepared copper plates, which are first

strongly silvered and then platinized, is still more advantageous on account of their greater roughness. To increase the constancy of the element, it is advisable to add some chloride of platinum to the dilute acid of the element. The electro-motive force of the Smee element is about 0.48 volt.

As previously mentioned, polarization can be entirely avoided only by allowing the electro-negative pole plate to dip in a fluid which, by combustion, reduces the hydrogen evolved to water, or, in other words, which immediately oxidizes the hydrogen to water. From this conviction originated the so-called *constant elements* with two fluids, the first of these elements being, in 1829, constructed by Becquerel, which, in 1836, was succeeded by the far more effective one of Daniell.

As most generally used, Daniell's element (Fig. 7) consists of a glass vessel, a copper cylinder, a porous clay cell, and a rod of zinc suspended in the latter. The glass vessel is filled with concentrated solution and a small piece of blue vitriol, and the porous clay cell with dilute sulphuric acid. The oxygen evolved on the electro-positive zinc oxidizes the latter, sulphate of zinc being formed, while the hydrogen separating on the electro-negative copper reduces from the blue vitriol solution a quantity of copper equivalent to it, which separates upon the electro-negative plate. However, after a comparatively short time of working, the dilute sulphuric acid is consumed for the formation of sulphate of zinc, the electro-motive force becoming very weak; the necessity of frequently renewing the dilute sulphuric acid is an inconvenience which the Daniell elements show more than any others. Furthermore, by the action of osmose blue vitriol solution gets into the porous cell, where it is decomposed by coming in contact with the zinc, the copper being separated upon the latter, whereby the effect is destroyed or at least very much weakened. The electro-motive force of the Daniell element is about 1 volt.

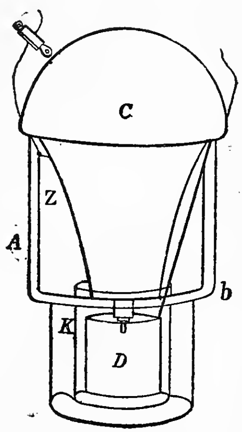
Fig. 7.



The *Meidinger element* may be considered a modified Daniell element. Like the Callaud element, it has no porous division, the mixture of the two fluids being prevented by their different specific gravities. The shape of the Meidinger element, as most generally used, is shown in Fig. 8.

Upon the bottom of a glass vessel, *A*, provided at *b* with a shoulder, stands a small glass cylinder, *K*, which contains the electro-negative copper cylinder *D;* from the latter a conducting wire leads to the exterior. Upon the shoulder, at *b*, rests the zinc cylinder *Z*, which is also provided with a conducting wire leading to the exterior. The balloon *C* closes the vessel by being placed upon it. The balloon is filled with pieces of blue vitriol and Epsom salt solution; the entire element is also filled with Epsom salt solution (1 part Epsom salt to 5 water). In the balloon *C* concentrated solution of blue vitriol is formed which flows into the glass cylinder *K;* if the circuit is not closed, the concentrated copper solution remains quietly standing in *K*, its greater specific gravity preventing it from rising higher and reaching the zinc. If, however, the circuit be closed, zinc is dissolved, while metallic copper is separated from the blue vitriol solution, and concentrated solution flows from the balloon *C* to the same extent as the blue vitriol solution in *D* becomes dilute by the separation of copper. Hence the action of the element remains constant for quite a long time, and of all the modified forms of Daniell's element consumes the least blue vitriol for a determined quantity of current; however, in consequence of its great internal resistance (9.90 ohms) its current-strength is small. The electro-motive force of the Meidinger element is 0.95 volt.

Fig. 8.



Grove, in 1839, substituted platinum for copper; the platinum dips in concentrated nitric acid, while the zinc cylinder stands in dilute sulphuric acid. The hydrogen liberated on the platinum is oxidized to water by the nitric acid, hyponitrous acid escaping

in the form of gas. The electro-motive force of the Grove element is at first double that of the Daniell element, but it soon abates on account of the dilution of the nitric acid by water. To prevent this weakening, concentrated sulphuric acid, which absorbs the water formed by the oxidation of the hydrogen, may be added to the nitric acid. Though the resistance of the Grove element is small (0.70 to 0.75 ohm), and its electro-motive force 1.70 to 1.90 volts, according to the concentration of the solutions, it is but seldom used on account of its costliness.

Bunsen, in 1841, replaced the expensive platinum by prisms cut from gas-carbon, which is still less electro-negative than platinum, and very hard and solid, so that it perfectly resists the action of the nitric acid. In place of the gas-carbon an *artificial carbon* may be prepared by kneading a mixture of pulverized coal and coke with sugar solution or syrup, bringing the mass under pressure into suitable iron moulds and glowing it with the exclusion of air. After cooling, the carbon is again saturated with sugar solution (others use tar, or a mixture of tar and glycerine) and again glowed with the exclusion of air, these operations being, if necessary, repeated once more, especially when great demands are made on the electro-motive force and solidity of the artificial carbons.

Figs. 9, 10, and 11 show the three forms of Bunsen's elements most generally used.

Fig. 9, which is the most convenient and practical form, consists of an outer vessel of glass. In this is placed a cylinder of zinc in which stands a porous clay cell, and in the latter the prism of gas-carbon. A band of copper is soldered or secured by means of a binding-screw to the zinc cylinder, while the prism of gas-carbon carries the binding-screw (armature), as seen in Fig. 8, in the upper part of which a copper sheet or wire is fixed for the transmission of the current. The outer vessel is filled with dilute sulphuric acid (1 part by weight of sulphuric acid of 66° Bé.—free from arsenic—and 15 parts by weight of water), and the porous cell with concentrated nitric acid of at least 36° Bé., or still better 40° Bé., care being had that both fluids have the same level.

In Fig. 10 the cylinder of artificial carbon is in the glass

vessel, while the zinc, which, in order to increase its surface, has a star-like cross-section, is placed in the porous clay cell. In this case the outer vessel is filled with concentrated nitric acid, and the clay cell with dilute sulphuric acid.

Fig. 9.

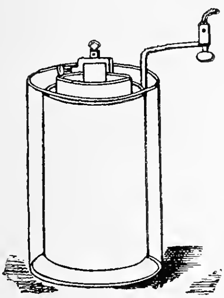


Fig. 10

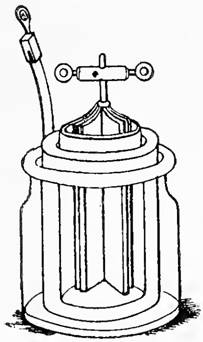
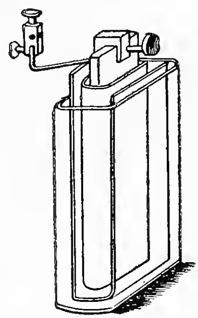
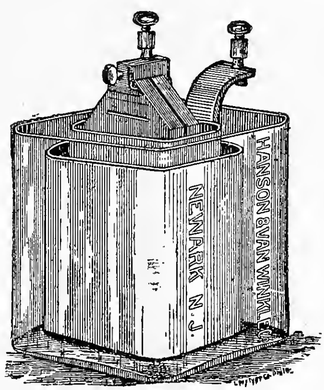


Fig. 11.



The form of the Bunsen element shown in Fig. 9 is more advantageous, because its effective zinc surface can be kept larger. Fig. 11 shows a plate element such as is chiefly used for bichromate batteries.

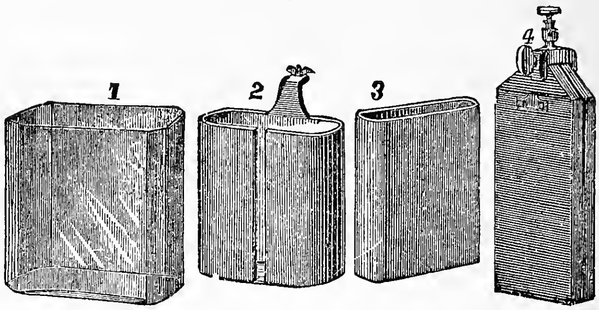
Fig. 12.



Improved Bunsen cell.—Fig. 12 shows an improved type of Bunsen cell for nickel-plating purposes, where the absence of power prevents the use of a dynamo machine. This cell fur-

nishes a large volume of current, as its internal resistance is low. It is an easy battery to set up and keep in working order. The batteries are set up by well amalgamating, inside and out, the zinc 2, Fig. 13, and placing it in the jar 1. Inside the zinc

Fig. 13.



place the porous cup 3, and within the porous cup the carbon 4, and then pour nitric acid in the porous cup. In the outer jar pour a mixture of 1 part sulphuric acid to 12 of water (previously mixed and allowed to cool). This acid mixture should cover the zinc or be on a level with the liquid in the porous cup. When the liquid in the outer jar becomes milky, withdraw it with a syringe or siphon, and refill, adding occasionally small quantities of nitric acid to the porous cup, and keeping the zinc thoroughly amalgamated by one of the methods given on page 30. A very good plan of amalgamating zinc is as follows: Dip in lye to remove grease, rinse, then dip in the dilute acid in the glass jar, and then brush over with about 2 ozs. of mercury contained in a little flannel bag.

Electropoion may be substituted for the nitric acid in the porous cup. This battery liquid consists of 1 lb. of bichromate of potash dissolved in 10 lbs. of water, to which $2\frac{1}{2}$ lbs. of commercial sulphuric acid have been gradually added.

The Bunsen elements are much used for electro-deposition, since they possess a high electro-motive force (1.88 volts) and, on account of slight resistance (0.25 ohm), develop considerable current-strength. Like the Grove elements, they have the inconvenience of evolving vapors of hyponitrous acid, which are not

only injurious to health, but also attack the metallic articles in the workshop. Wherever possible they should be placed in a box at such a height that they may be readily manipulated. This box should have means of ventilation in such a way that the air coming in at the lower part will escape at the top through a flue, and carry away with it the acid fumes disengaged. It is still better to keep the elements in a room separate from that where the baths and metals are to be operated upon. Furthermore, as the nitric acid becomes diluted by the oxidation of the hydrogen, and the sulphuric acid is consumed in the formation of sulphate of zinc, the acids have to be frequently renewed.

To avoid the acid vapors, as well as to render the elements more constant, A. Dupré has proposed the use of a 30 per cent. solution of bisulphate of potash in water in place of the dilute sulphuric acid, and a mixture of water 600 parts, concentrated sulphuric acid 400, sodium nitrate 500, and bichromate of potash 60, in place of the nitric acid.

The following method can be recommended: The outer vessel which contains the zinc cylinder is filled with a moderately concentrated (about 30 per cent.) solution of bisulphate of potash or soda, and the clay cell with solution of chromic acid—1 part chromic acid to 5 parts water. As soon as the electro-motive force of the element abates, it is strengthened by the addition of a few spoonfuls of pulverized chromic acid to the chromic acid solution. It is better to use the chromic acid in the form of powder, which is especially prepared for this purpose, than a chromic acid solution produced by mixing solution of bichromate of potash with sulphuric acid, the tendency of such a solution to form crystals exerting a disturbing effect.

In using nitric acid it is also advantageous to pour a 0.39 to 0.78 inch thick layer of oil upon the acid to decrease the vapors.

The binding-screws which effect the metallic contacts must of course be frequently inspected and cleaned, which is best done by means of a file or emery paper. It is advisable to place a piece of sheet platinum between the binding surface of the carbon armature and the carbon in order to prevent the acid rising through the capillarity of the carbon from acting directly upon the armature (generally brass or copper). To prevent the acid from

rising, the upper portions of the carbons may be impregnated with paraffine. For this purpose the carbons are placed $\frac{3}{4}$ to 1 inch deep in melted paraffine and allowed to remain 10 minutes. On the sides where the armature comes in contact with the carbon, an excess of paraffine is removed by scraping with a knife-blade or rasp.

Manipulation of Bunsen elements.—Before using the elements the zinc cylinders should be very carefully amalgamated according to one of the methods given on p. 30. The nitric acid need not be pure, the crude commercial acid suffices, but it should be as concentrated as possible and show at least 36° Bé. For the prisms it is best to take carbon produced in gas-houses using coal without the addition of brown coal, the electro-motive force of the latter being less. If artificial carbon is employed, it should be examined as to its suitability, the non-success of the plating process being frequently attributed to the composition of the bath, when in fact it is due to the defective carbons of the elements. In order to avoid an unnecessary consumption of zinc and acid the elements are taken apart when not in use, for instance, over night. Detach the brass armature of the carbon prism and lay it in water to which some chalk has been added; lift the carbon from the clay cylinder and place it in a porcelain dish or earthenware pot; empty the nitric acid of the clay cell into a bottle provided with a glass stopper; place the clay cell in a vessel of water, and finally take the zinc cylinder from the dilute sulphuric acid and place it upon two sticks of wood laid across the glass vessel to drain off. In putting the elements together the reverse order is followed, the zinc being first placed in the glass vessel and then the carbon in the porous clay cell. The latter is then filled about three-quarters full with used nitric acid, and fresh acid is added until the fluid in the clay vessel stands at a level with that in the outer vessel. The cleansed brass armature is then screwed upon the carbon prism. Finally, add to the dilute sulphuric acid in the outer vessel a small quantity of concentrated sulphuric acid saturated with mercury salt.

It is advisable to have at least a duplicate set of porous clay cells, and in putting the elements together to use only cells which have been thoroughly soaked in water. The reason for this is as

follows: The nitric acid fills the pores of the cell, and, finally reaching the zinc of the outer vessel, causes strong local action and a correspondingly rapid destruction of the zinc. It is, therefore, best to change the clay cells every day, allowing those which have been in use to lie in water the next day with frequent renewal of the water. For the same reason the nitric acid in the clay cell should not be at a higher level than the sulphuric acid in the outer vessel.

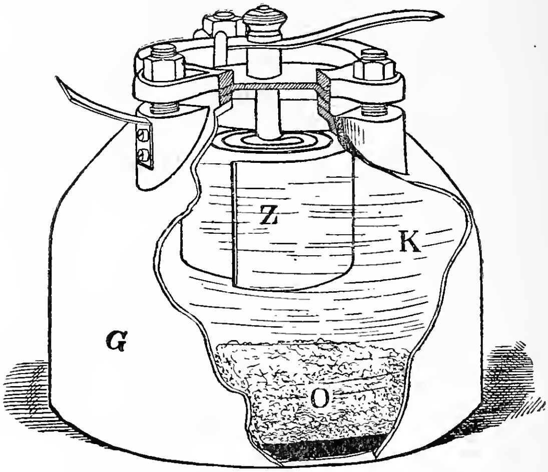
When the Bunsen elements are in steady use from morning till night, the acids will have to be entirely renewed every third or fourth day. The solution of sulphate of zinc in the outer vessel is thrown away, while the acid of the clay cells may be mixed with an equal volume of concentrated sulphuric acid, and this mixture can be used as a preliminary pickle for brass and other copper alloys.

The *Leclanché* element (zinc and carbon in sal ammoniac solution with manganese peroxide as a depolarizator) need not be further mentioned, it not being adapted for regular use in electroplating. It is in very general use for electric bells, its great recommendation being that, when once charged, it retains its power without attention for several years.

Lallande and Chaperon have recently introduced a copper oxide element, shown in Fig. 14, which possesses several advantages. It consists of the outer vessel *G*, of cast-iron or copper, which forms the negative pole surface, and to which the wire leading to the anodes is attached, and a strip of zinc, *Z*, coiled in the form of a spiral, which is suspended from an ebonite cover carrying a terminal connected with the zinc. The hermetical closing of the vessel *G* by the ebonite cover is effected by means of three screws and an intermediate rubber plate. Upon the bottom of the vessel *G* is placed a 3 to 4 inch deep layer of copper oxide, *O*, and the vessel is filled with a solution of 50 parts of caustic potash in 100 of water. When the circuit is closed, decomposition of water takes place, the oxygen which appears on the zinc forming with the latter zinc oxide, which readily dissolves in the caustic potash solution, while the hydrogen is oxidized with the simultaneous reduction of copper oxide to copper. When the element is open, *i. e.*, the circuit not closed, neither the zinc nor the copper

oxide is attacked, and hence no local action nor any consumption of material takes place. The electro-motive force of this element is 0.98 volt, and its internal resistance very low. It is remarkably constant and is well adapted for electro-plating purposes by

Fig. 14.



using two of them for one Bunsen element. The following rules have to be observed in its use. It is absolutely necessary that the ebonite cover should hermetically close the vessel *G*, as otherwise the caustic potash solution would absorb carbonic acid from the air, whereby carbonate of potash would be formed, which would weaken the exciting action of the solution. Further, the vessel *G* forming the one pole must be insulated from the other as well as from the ground, as otherwise a loss of current or defective working would be the consequence.

The elements of Marié Davy, Niaudet, Duchemin, Sturgeon, Trouville, and others, being of little value for practical use, may be passed over.

Duns's potash element.—On account of its great electro-motive force (1.6 volts) and slight internal resistance this element would be well adapted for electro-plating purposes, if depolarization were effected more rapidly than is actually the case. Its construction is as follows: In a glass vessel stands a carbon cylinder

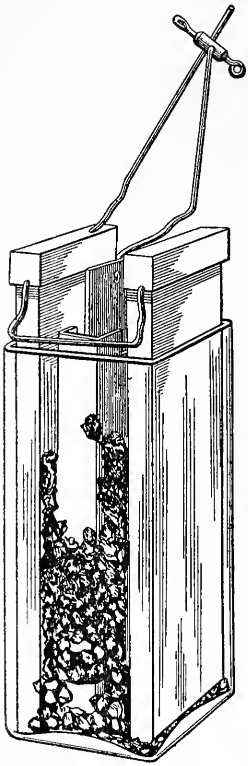
closed below, and in the centre of the carbon cylinder a clay cell. The space between the clay cell and the interior wall of the carbon cylinder is filled five-sixths full with pieces of carbon. In the clay cell stands an amalgamated strip of zinc or zinc cylinder to which the conducting wires are soldered, the place of soldering, as well as the wire as far as it comes in contact with the fluid, being covered with gutta-percha. The edge of the carbon cylinder is coated with paraffine and carries the pole binding-screw. The filling of the element is effected by laying potassium permanganate in crystals upon the layer of carbon between the clay and carbon cylinders, and pouring a solution of 1 part of pure caustic potash in 2 of water into the clay cell, the pouring being continued until the fluid runs over the clay cell upon the potassium permanganate and the layer of carbon, and finally fills the outer vessel up to about the breadth of two fingers from the edge. The action of the element is as follows: When the element is closed decomposition of water takes place, the oxygen combining with the zinc to form zinc oxide, which is dissolved by the potash lye, while the hydrogen is oxidized on the positive pole by the potassium permanganate. The latter, to be sure, contains much oxygen, and acts very energetically, but as it diffuses very slowly, depolarization, *i. e.*, the removal of the hydrogen, is not so quickly effected as, for instance, in the Bunsen element, where the nitric acid rapidly diffuses. Hence with a slight external resistance, for instance, baths where the element has to furnish large quantities of current, the electro-motive force sinks very rapidly and with it the current-strength, and, therefore, the element is only suitable for electro-plating purposes when a current need only for a short time be produced, but not for permanent work. In the first case it offers the advantage of being always ready for use, evolving no vapors, and when not in use consuming no material. It is prudent to protect this element from the action of the carbonic acid of the air by a close cover.

The element shown in Fig. 15 has recently been patented in Germany, and is described by Knaffe and Kiefer,* of Vienna, as follows: The element consists of a combination of zinc and car-

* Neueste Erfindungen und Erfahrungen, vol. xviii. p. 308.

bon. The zinc plate is $9\frac{1}{2}$ inches long, $4\frac{3}{4}$ inches wide, and of the thickness of pasteboard. It is amalgamated according to a new process. It is placed between two carbon plates of equal size, the surface of which is twice that of the zinc. The carbon plates are connected with the conducting wires in such a manner as to prevent oxidation of the binding-screws and to secure constant contact. The zinc plate is suspended in a neutral salt solution in a clay cell, the space between the latter and the carbon plates being filled with pieces of carbon. The consumption of zinc is very small. The principal advantage of this new element is, however, the depolarizing fluid of peculiar composition and powerful effect.

Fig. 15.



The element has an electro-motive force of 1.9 volts, an internal resistance of 0.17 ohm, and a constancy such as has never before been attained with primary elements, 1 volt ampère lasting for 100 hours.

We will add a few words in regard to *plunge* or bichromate batteries. They consist of a number of separate voltaic cells connected so as to form a single cell or electric source, and the plates of which are so supported as to be capable of being simultaneously placed in or removed from the exciting fluid. For our purposes it will suffice to mention the *Bunsen plunge battery*, shown in Fig. 16. For constructive reasons only one fluid is used, into which the zinc as well as the carbon plates dip, a solution of chromic acid prepared by dissolving 10 parts of bichromate of potash and $\frac{1}{2}$ part of mercuric sulphate in 100 parts of water, and adding 18 parts of pure concentrated sulphuric acid, being employed. More advantageous is a solution of chromic acid in the form of powder

in water, in the proportion of 1 : 5, for the same reason as given on p. 37.

Fig. 16.

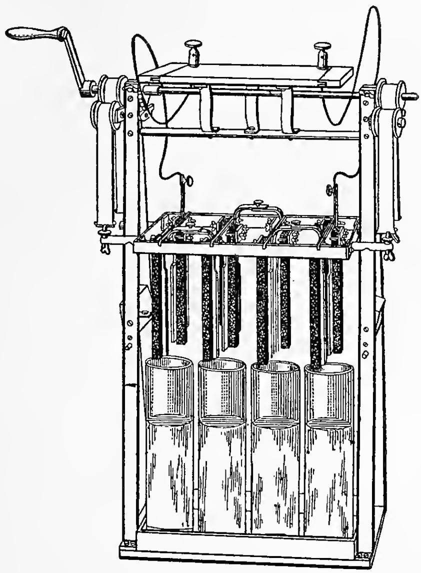
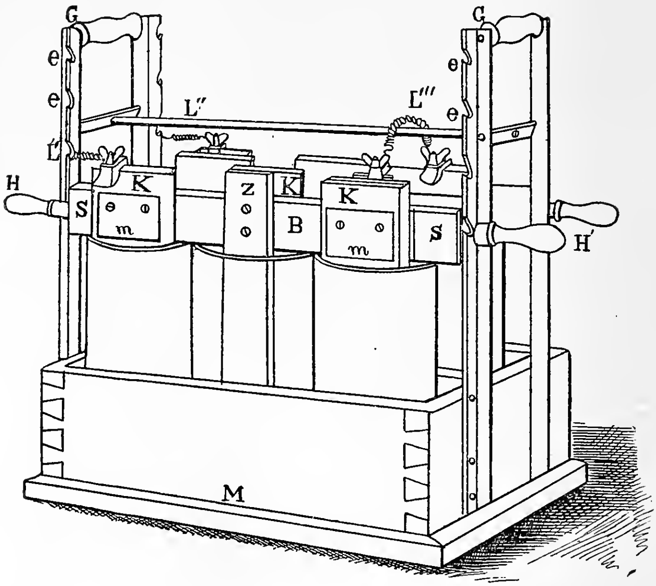


Fig. 17 shows a bichromate battery as constructed by Fein. Into the 6 element-vessels standing in two rows in the wooden box *M* dip the zinc and carbon plates, which are secured to wooden cross-pieces provided with handles, and may be maintained at any desired height by the notch *e* in the standard *G*. According to the current-strength required, the plates are allowed to dip in more or less deeply.

Fig. 18 shows a bichromate battery as constructed by Keiser & Schmidt.

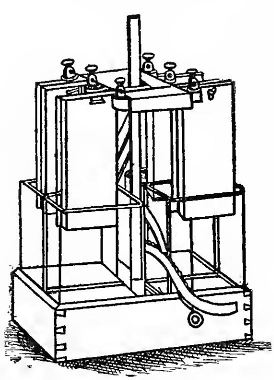
In using the above-mentioned chromic acid solution, which has been recommended by Bunsen, the elements at first develop a very strong current, which, however, in a comparatively short time becomes weaker and weaker. The current-strength can be increased by adding at intervals a few spoonfuls of pulverized chromic acid to the chromic acid solution, which, however, finally remains without effect, when the battery has to be freshly filled.

Fig. 17.



Hence, these batteries are not suitable for electro-plating operations requiring a constant current for some time.

Fig. 18.



For temporary use, for instance, by gold-workers and others, for gilding or silvering small articles, the bottle-form of the bichromate element (Fig. 19) may be advantageously employed. In the bottle *A* two long strips of carbon united above by a metallic connection are fastened parallel to one another to a vulcanite stopper, and are there connected with the binding-screw; these form the negative element, and pass to the bottom of the bottle; between them is a short thick strip of zinc attached to a brass rod passing stiffly through the centre of the vulcanite cork, and connected with the binding-screw. The zinc is entirely insulated from the carbon by the

vulcanite, and may be drawn out of the solution by means of the brass rod as soon as its services are no longer required.

This bichromate element is excellent for purposes requiring strong currents, where long action is not necessary. As this element readily polarizes, it cannot be advantageously employed continuously for any considerable period of time. It becomes depolarized, however, when left for some time on open circuit. The element gives an electro-motive force of about 1.9 volts.

In Stoehrer's battery (Fig. 20) two acids, dilute sulphuric acid and concentrated nitric acid, are used. The porous clay cell is

Fig. 19.

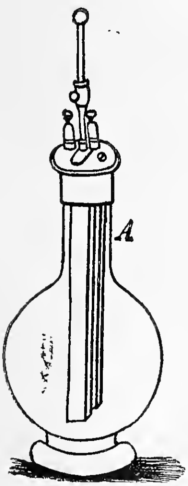
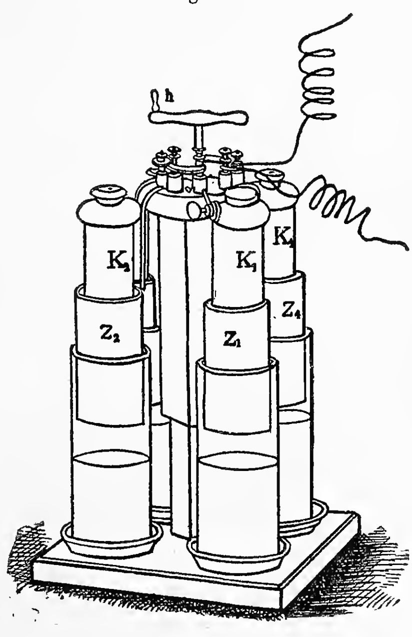


Fig. 20.



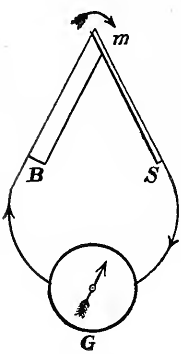
omitted, the massive carbon cylinders *K K*, etc., being provided with a cavity reaching almost to the bottom, which is filled with sand and nitric acid. The contact of the carbon and zinc cylinders is prevented by glass beads imbedded in the carbon cylinders.

B. *Thermo-electric Piles.*

Though thermo-electric piles are only used in isolated cases for electro-plating operations, for the sake of completeness their nature and best known forms will be briefly mentioned.

In the year 1822 Professor Seebeck, of Berlin, discovered a new source of electricity, namely, inequality of temperature and conducting power in different metals, or in the same metal in different states of compression and density. When two pieces of different metals, connected together at each end, have one of their joints more heated than the other, an electric current is immediately set up. Of all the metals tried, bismuth and antimony form the most powerful combination.

Fig. 21.

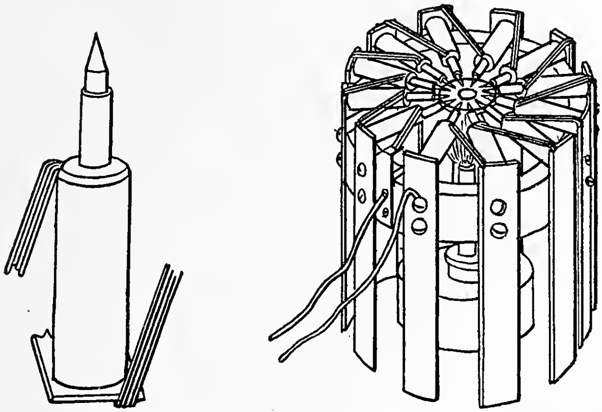


In Fig. 21 *Bm* represents a bar of bismuth, and *mS* a bar of antimony soldered to the bismuth bar. By leading wires from *B* and *S* to a galvanoscope, *G*, and heating the point of junction *m*, the needle of the galvanoscope is deflected. From this it may concluded that an electric current circulates in the closed circuit *GB mS G*. By a closer examination the direction of the current may be recognized, it flowing on the heated point of junction from the bismuth to the antimony, and in the connecting wire of the ends of the rods which remain cold, from the antimony to the bismuth. The current is the stronger the greater the difference in the temperature of the point of junction and the free ends of the bars. Hence the electric current will be especially strong when the place of junction is heated and the ends *B* and *S* are at the same time cooled off. A combination as above described is called a *thermo-electric couple,* and the electricity obtained in this manner *thermo-electricity.* By a suitable combination of several or many of such couples, a thermo electric pile is obtained.

Noe's thermo-electric pile (Fig. 22) consists of a series of small cylinders, composed of an alloy of $36\frac{1}{2}$ parts of zinc and $62\frac{1}{2}$ parts of antimony for the positive element, and stout German silver as the negative element. The junctions of the elements are

heated by small gas-jets, and the alternate junctions are cooled by the heat being conducted away by large blackened sheets of thin

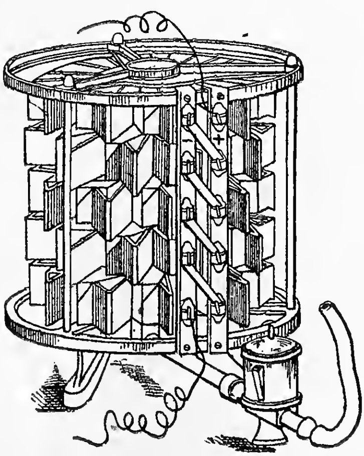
Fig. 22.



copper. A pile of twenty pairs has an electro-motive force of 1.9 volts.

Clamond's thermo-electric pile (Fig. 23) consists of an alloy of 2 parts antimony and 1 of zinc for the negative metal, while for

Fig. 23.

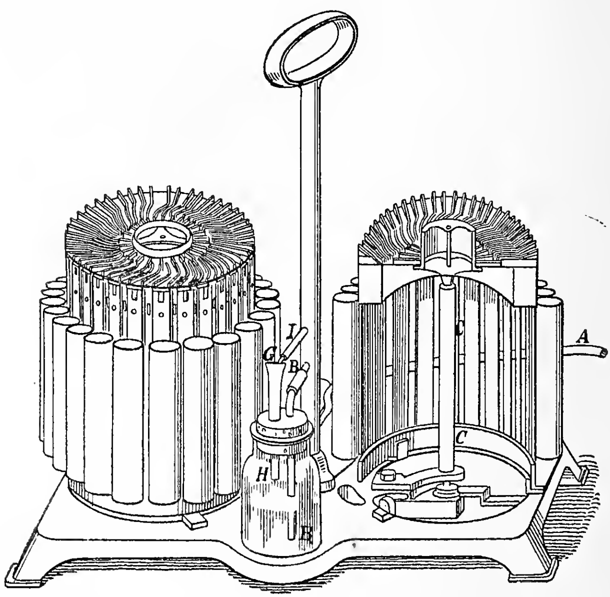


the positive element ordinary tinned sheet-iron is employed, the current flowing through the hot junction from the iron to the

alloy. To insure a good contact between the two metals a strip of tin-plate is bent into a narrow loop at one end. This portion is then placed in a mould and the melted alloy poured around it, so that it is actually imbedded in the casting. The pile shown in the illustration consists of five series, one placed above the other. Each series has ten elements grouped in a circle, and is insulated from the succeeding series by a layer of cement, composed of powdered asbestos moistened with a solution of potassium silicate. With the consumption of about 6½ cubic feet of gas per hour, such a pile precipitates 0.7 oz. of copper, which corresponds to an electro-motive force of about 17 ampères.

Hauck's thermo-electric pile.—An essential defect of Clamond's thermo-electric pile consists in that the junctions of the dissimilar

Fig. 24.

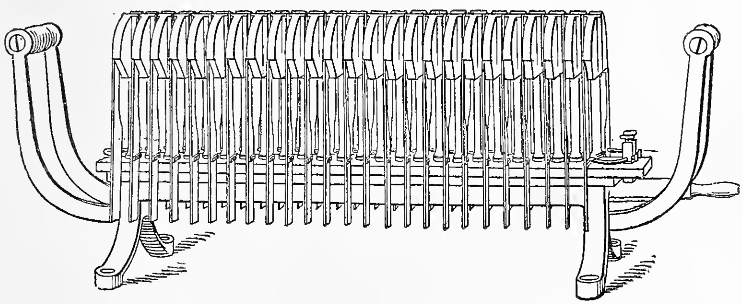


metals are subjected to ready destruction by being exposed to the direct action of the flame. Further, it is very difficult, or at least inconvenient, to make repairs, since in such a case it may become necessary to take the entire pile apart. Hauck has successfully

overcome these defects by adopting the principle of indirect heating as well as by giving the couples a more suitable form and by improving the alloy. The couples form four-sided wedges to which are attached cast-iron pieces that transfer the heat of the gas-burner to the couples. The electro-motive force of a single couple is $\frac{1}{10}$ that of a Daniell element. Fig. 24 shows a combination of two piles standing upon a common plate, one of the piles being given in cross-section. The glass-vessel *H*, with the tubes *B*, *G*, *R*, *I*, serves as a regulator for the gas-pressure. The pile shown in the illustration serves for the production of metallic deposits on a small scale, especially for analytical examinations. Hauck, however, also furnishes combinations of three larger piles.

Gülcher's thermo-electric pile, invented in 1890, is shown in Fig. 25. It is arranged for gas-heating, and with a constant supply of gas requires a pressure-regulator. The negative electrodes consist of nickel and the positive electrodes of an antimony alloy,

Fig. 25.



the composition of which is kept secret. The negative nickel electrodes have the form of thin tubes and are secured in two rows in a slate plate, which forms the termination of a gas conduit with a U-shaped cross-section beneath it. Corresponding openings in the slate plate connect the nickel tubes with the gas conduit, the latter being connected by means of a rubber tube with the pipe supplying the gas. Thus the gas first passes into the conduits, next into the nickel tubes, and leaves the latter through six small holes in a soap-stone socket screwed in the end of each tube. On leaving these sockets the gas is ignited and the small blue flames heat the connecting piece of the two electrodes. This connecting

piece consists of a circular brass plate placed directly over the soap-stone socket. One end of it is soldered to the nickel tube, while the other ends, towards the top, in a socket in which are cast the positive electrodes. The latter have the form of cylindrical rods with lateral angular prolongations. To the ends of these prolongations are soldered long copper strips secured in notches in the slate plate. They serve partially for cooling off and partially for connecting the couples. For the latter purpose each copper strip is connected by a short wire with the lower end of the nickel tube belonging to the next couple. When the pile is to be used, the gas is ignited in one place, the ignition spreading rapidly through the entire series of couples. In about 10 minutes the junctions of the metals have attained their highest temperature and the pile its greatest power, which, with a constant supply of gas, remains unchanged for days or weeks.

In view of the conversion of the heat produced by the combustion of the gas into electricity, the useful effect of the thermo-electric pile can be considered only a very slight one. One cubic meter of ordinary coal-gas produces on an average 5200 heat-units, hence 200 litres per hour referred to one second $\frac{1}{5} \cdot \frac{1}{60} \cdot \frac{1}{6} \cdot 5200 = 0.29$ heat-unit. These correspond to 1208 volt-ampères, 1 volt-ampère being equal to 0.00024 heat-unit. Hence, in Gülcher's thermo-electric pile, which at present produces the greatest useful effect, not much more than 1 per cent. of the heat is utilized in the entire circuit, and about $\frac{1}{2}$ per cent. in the outer circuit.

Although thermo-electric piles may be, and are occasionally, used for electro-plating operations, they cannot compete with dynamo-electric machines driven by steam, which as regards the consumption of heat are at least five times more effective. They can only be used in place of galvanic batteries, they having the advantage of being more convenient to put in operation, more simple, cleanly, odorless, and requiring less time for attendance. But, on the other hand, their original cost is comparatively large, it being ten to twenty times that of Bunsen elements. Thus, for instance, Gülcher's thermo-electric pile costs $37.50 in Germany, to which have to be added $5 for the gas-pressure regulator, if required.

C. *Magneto- and Dynamo-electric Machines.*

The principle of induction upon which the dynamo-electric machines are based has been explained on p. 21. Faraday, in 1831, made the important discovery that by moving a coil of wire in the presence of a magnet a current of electricity was generated in the coil, or, *vice versa*, by moving the magnet and holding the coil stationary a like result was obtained; thus a current of electricity was produced either by moving a wire in the presence of a stationary magnet, or by moving a magnet in the presence of a stationary wire.

The intensity of the current thus obtained depends on the strength of the magnet and on the velocity with which the magnet or coil is moved through the magnetic field. Upon these simple facts is based the whole of the recent important developments of electrical science.

Before describing the various attempts made to devise some mechanical means whereby the different elements which produced the temporary or momentary currents could be combined, so as to collect them, and cause them to flow in rapid succession, the one after the other, without interruption, it will be well to remember that the necessary elements for producing these induced electric currents are simply a bar magnet and an insulated coil of wire. It will also be well to remember that every magnet, no matter what its form, has two poles—a north and a south pole—and each of these poles exerts a certain influence in its immediate neighborhood, the space thus affected being termed the *magnetic field* or the *region of the lines of force.* The attraction or magnetic force of these lines varies as the inverse ratio of the square of the distance; therefore, the nearer the magnet the greater the intensity of the magnetism. Faraday proved that these lines, which he designated lines of force, showed by their position the direction of the magnetic force, and by their number its intensity. By passing a coil of wire through this field, so as to cause it to cut, as it were, a number of these lines of force, a current of electricity will be generated in the coil; and if it can be so arranged that a number of these coils will pass in rapid succession through

the magnetic field, we shall have a series of impulses giving us practically a continuous stream of electricity.

Thus a magneto-electric or dynamo-electric machine is simply a machine for the conversion of mechanical energy into electrical energy by means of magneto-electric induction. The term dynamo-electric machine is also applied to a machine by means of which electrical energy is converted into mechanical energy by means of magneto-electric induction. Machines of the latter class are generally called *motors*, those of the former *generators*.

Prof. S. P. Thompson defines a dynamo-electric machine as follows:—

"A machine for converting energy in the form of mechanical power into energy in the form of electric currents, or, *vice versa*, by the operation of setting conductors (usually in the form of coils of copper wire) to rotate in a magnetic field, or by varying a magnetic field in the presence of conductors."

The term dynamo was first applied to such machines because of the form in which this machine first appeared, viz., the series-wound machine; it was self-acting, or required no excitement other than what it received by the rotation of its armature in the field of its magnets, or, indeed, in the field of the earth.

A dynamo-generator, or a dynamo-electric machine proper, consists of the following parts:—

1. The revolving portion, usually the *armature*, in which the electro-motive force is developed which produces the current.

2. The *field magnets* which produce the field in which the armature revolves.

3. The *pole pieces*, or free terminals of the field magnets.

4. The *commutator*, by which the currents developed in the armature are caused to flow in one and the same direction. In alternating machines and in some continuous current dynamos this part is called the *collector*, and does not rectify the currents.

5. The *collecting brushes*, that rest on the *commutator cylinder* and take off the current generated in the armature.

The number of such dynamo machines is legion. In each case the arrangement of the armature of the magnets and of the commutators is varied, but the principle is always the same—coils of

insulated wire being caused to cut through magnetic fields, as already explained.

The first attempt to devise an electrical machine was made by Pixii, who, in 1832, constructed a machine consisting of a permanent magnet, which he caused to revolve in front of the iron cores of a pair of bobbins, forming an electro-magnet. This invention was improved by other workers in the field of science, especially by Saxton and Clarke, both of whom succeeded in producing very useful electric generators, in which the mechanical arrangement is the reverse of that in Pixii's—*i. e.*, the magnets are fixed and the coils of wire movable. And it is on this plan that all the subsequent machines have been constructed, as affording better results than where the coils are stationary and the magnets movable.

A great improvement was made in 1857, by Dr. W. Siemens, of Berlin. It consisted essentially in a new form of armature, which, owing to its simplicity and cheapness, is still used for many purposes, especially for electro-plating and laboratory work. It is composed of a cylinder of iron in which deep longitudinal grooves are cut resembling in section the letter H. In these grooves is wound lengthwise a single coil of wire, the two ends of which being joined to a split tube of copper on the axle, form the commutator, from which the current is taken off by brushes or springs rubbing against it. By this longitudinal armature the advantage is gained of cutting the greatest number of lines of force when rotated between the poles of a series of adjacent magnets.

One of the most important inventions for the construction of electrical machines is the *ring conductor* by Pacinotti (1860). With the use of this ring conductor continuous currents of the same direction can be produced without the assistance of a commutator.

Next in order comes the important discovery made simultaneously, but independently, by Dr. W. Siemens and Sir C. Wheatstone—a discovery which marks the transition of the *magneto*-electric machine to that type most in practice at present—the *dynamo* machine, called for convenience the *dynamo*. What Siemens and Wheatstone discovered was this: That a current of electricity could be generated in the coils of the armature

by the feeble residual magnetism in the iron cores of the electro-magnets, and that by passing this feeble current round the magnets their magnetism would be strengthened, which in turn would produce a stronger current in the armature, and this current would again react on the magnets rendering them more powerful, this action going on until the limit of saturation is attained; for it must be understood that this mutual accumulation cannot go on indefinitely, the magnetism in the iron cores cannot be intensified beyond a certain point, and this point depends on and is controlled by the scientific conditions on which the machine is constructed.

Machines constructed on this principle are called, as stated, dynamo machines, to distinguish them from those previously used in which the magnets were permanently magnetized, thus causing the division of electric generators into two great classes, viz., *magneto* and *dynamo* machines, which are subdivided into two varieties—one called the *continuous* current machine, furnishing currents in the same direction, and the other the *alternating* current machine, wherein the current is rapidly reversed or its direction changed many times a minute.

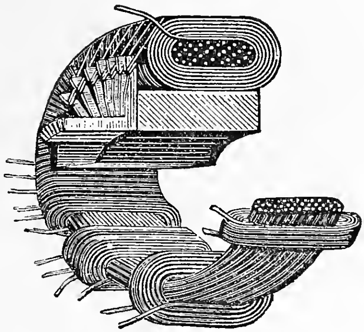
An essential difference between continuous and alternating current machines is that the former may be self-exciting, whereas the latter must have a separate excitor or must be a magneto machine. The cores of the electro-magnets, it may be mentioned, are of cast-iron, in which there is always a feeble residual magnetism. It is also easier to magnetize iron than steel, although, when the latter is once magnetized, it retains its magnetism for an indefinite period.

It is not within the province of this work to describe in detail all the forms of dynamos, it being sufficient for our purpose to discuss those which are adapted to and are used for electro-plating uses. If we mention the Gramme machine first, it is not because it is superior to other machines, but because M. Gramme, its inventor, was the first to utilize the idea suggested by Dr. Pacinotti, of using an iron ring as a revolving electro-magnet, which, in place of having fixed revolving poles, had poles which travelled continuously through the whole circumference of the ring.

Fig. 26 shows the Gramme armature in such a way as to

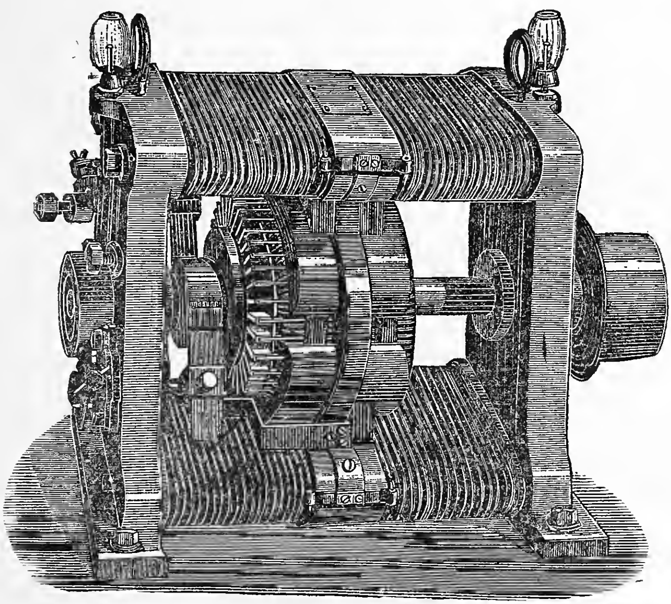
allow its construction to be seen. The core or centre of the ring consists of a bunch of soft iron wires; the wire system

Fig. 26.



wound about the core is formed of different spools, the initial wire of which is soldered to the terminal wire of the neighboring

Fig. 27.

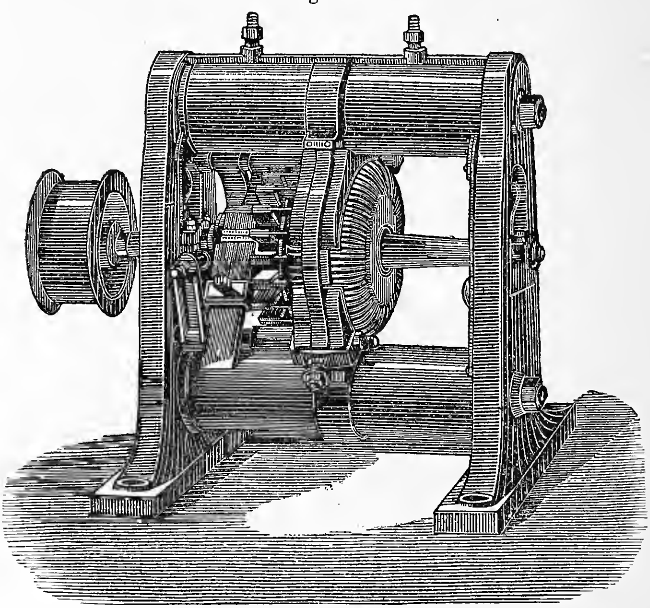


spool, so that all the spools of the ring form a single uninterrupted conductor. The soldered places lie all on one side of the ring,

and are fastened to flat copper strips bent at right angles and insulated from one another by a non-conducting mass which forms the commutator through which the axle passes. The armature revolves between the poles of the electro-magnets secured to the sides of the machine, as shown in Fig. 27. As the ring is revolved a current is generated and flows out with every change in its position. The current so made is carried out by wire brushes which press upon the terminal plates of the wires in the ring.

In the modern Gramme dynamos (Fig. 28) for galvano-plastic purposes, which have to furnish a considerable volume of current of

Fig. 28.

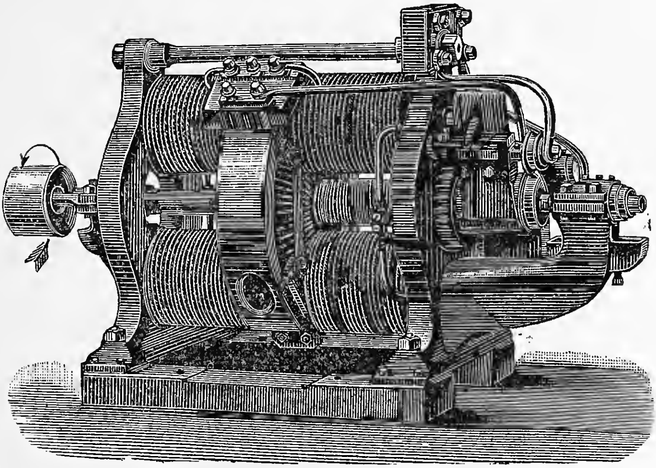


slight electro-motive force, the inducting magnets are surrounded by broad copper bands instead of being wound about with copper wire, and the armature is built up of stout copper rods, because the less resistance the copper windings have the greater the volume of current which is produced, while, *vice versa*, the tension increases with their resistance. Hence, machines for electro-plating purposes, which have to furnish quantities of current of

slight tension, are wound about with stout copper wire, while those for illuminating purposes, which must furnish currents of high tension, are wound about with thin copper wire. For this reason machines constructed for galvano-plastic use and for nickelling, coppering, brassing, etc., are not suitable for illuminating purposes, and, *vice versa*, machines constructed for electric lighting cannot suitably be employed for galvanic purposes.

A disadvantage of the Gramme machine is that only the portion of the copper windings on the outside of the ring conductor is in the magnetic field of the poles of the electro-magnets, so that only a comparatively small portion of the inductor is exposed to the inductive action of the magnets. Hence, in order to furnish correspondingly strong currents, the ring inductor must revolve very rapidly, the three sizes or numbers of Gramme machines mostly employed for galvano-plastic purposes making in fact from 1500 to 2000 revolutions per minute, whereby the bearings are more rapidly worn out than with machines running at less speed and, besides, more power is consumed.

Fig. 29..

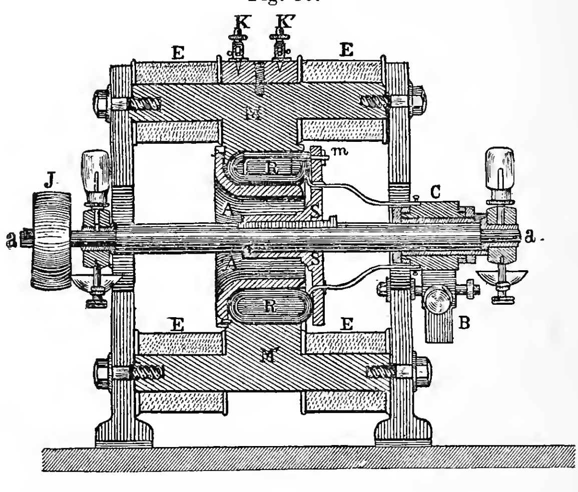


This evil led S. Schuckert, of Nürenberg, to construct a machine in which a *flat* ring is successfully used as an inductor, which stands almost entirely under the inductive influence of the

electro-magnets. Schuckert's flat ring machine is shown in Fig. 29. The core of the machine consists of thin sheet ribbands insulated one from another, whereby greater solidity is attained; the commutator and brushes are similar to those of the Gramme machine. The number of revolutions varies for the different sized machines from 500 to 1500 per minute. It is almost noiseless in action and is exceedingly well constructed. The formation of sparks on the contact-surface of the brushes with the commutator is scarcely perceptible, which secures the durability of the latter.

Fein, of Stuttgart, has endeavored to overcome the defect of the Gramme machine in a different manner. In these machines the polar extensions of the magnets *M* and *M'* (Fig. 30) are elongated to a sort of drum, *A A*, which leads into the interior of the inductor ring, whereby the greater portion of the windings is also brought into the magnetic fields of the electro-magnets.

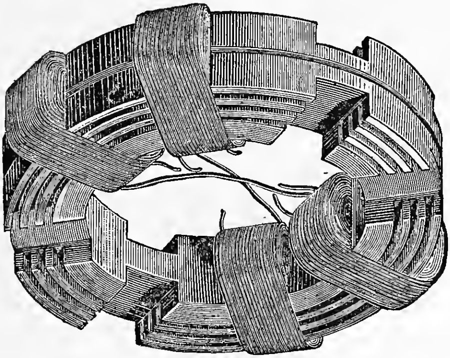
Fig. 30.



Closely resembling the Gramme machine in its general outline, but differing materially in construction and action, is that known as the Brush dynamo. Its armature, though consisting of a ring like that of Gramme's, is, however, differently built up. At intervals around the ring a number of transverse grooves are formed, in which are wound the coils or bobbins, all in the same direction; and instead of forming a continuous circuit, as in the

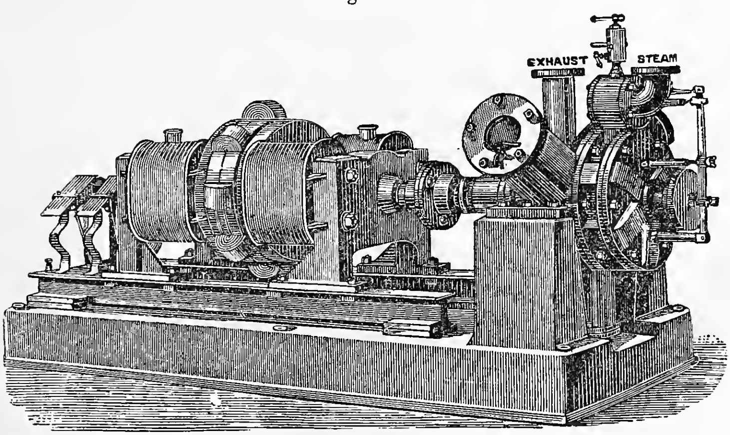
Gramme, each diametrically opposite pair of coils is joined to each other by one end of each coil, while the other ends of the pair (*i. e.*, the ends conveying the current) are connected to the commutator. Fig. 31 illustrates the ring, showing the opposite coils joined up as described. Four coils are removed to show its

Fig. 31.



construction. A series of deep concentric grooves will be observed formed in the ring, their object being to reduce the mass

Fig. 32.



of iron, and also to facilitate ventilation, thereby preventing the tendency to heat while the machine is working.

Fig. 32 represents the complete Brush machine set in motion

by a Brotherhood motor with three cylinders, the usual speed of the machine being about 750 revolutions per minute.

The machines built by Siemens & Halske, in which the cylinder-inductor invented by Hofner-Altenbeck is used, show a different construction from those previously described. A detailed explanation of the cylinder-inductor would lead us too far. It consists of a hollow iron cylinder, which revolves with the shaft, and about which the wires are wound parallel to the revolving axis in such a manner that no wire-windings are in the interior of the core (cylinder). The wire spirals wound about the cylinder are divided into sections, which are so connected one with another as to form a single connected wire conductor. The terminal wires of the separate sections are connected to the segments of the commutator, so that both the currents generated in the wire system always meet from an opposite direction in two portions of the commutator opposite to one another. The commutator is constructed according to the Gramme system, and has, of course, as many segments as there are sections wound upon the cylinder. A real advantage of the machine is that the greater portion of the wire-windings of the cylinder-inductor is in the magnetic field.

Fig. 33.

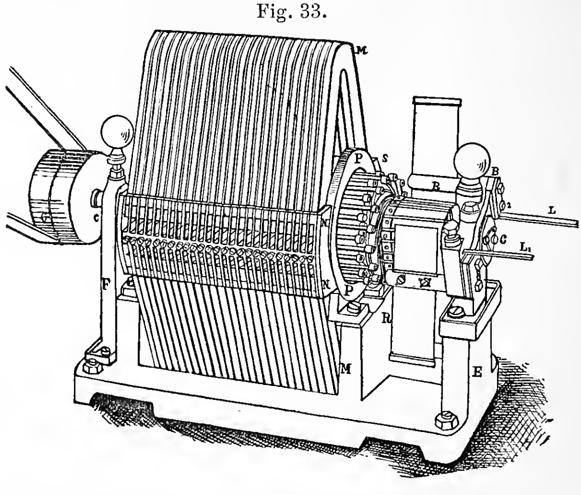
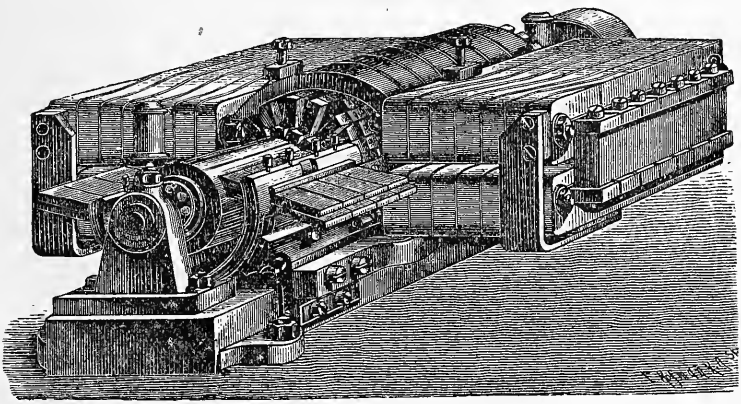


Fig. 33 shows a Siemens & Halske magneto-electric machine with cylinder-inductor.

Two series of 25 V-shaped magnets each are placed above and below, so that their poles of a similar name are opposite to one another, the poles of a similar name of the upper and lower magnets being connected one with another by arched pieces of soft iron. In the space thus formed between the upper and lower magnets, the cylinder-inductor revolves, the generated currents being carried away from the commutator by the brushes *R* and *R'*.

In Siemens & Halske's dynamo-electric machines for electro-metallurgical purposes (Fig. 34) the plate magnets are wound

Fig. 34.

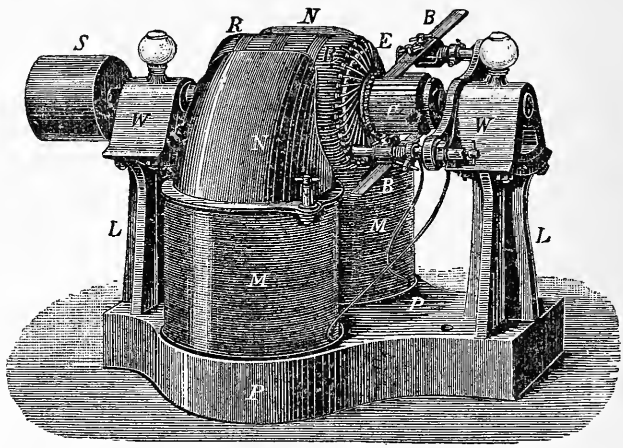


about with square copper rods, in smaller machines with stout copper wire, while instead of spirals the inductor carries copper ribbands, which are connected with the commutator by suitably bent pieces.

Fig. 35 shows the Kröttlinger machine constructed by Kröttlinger, of Vienna. It consists of a strong iron base, *P*, from which rise two short cylindrical electro-magnets, *M M*, which have a semicircular shaft on the upper end *N*, and closely embrace the ring *R*. The standards *L* are cast in one piece with the base *P*, and carry the bearings *W W*. The core of the ring *R* consists of separate disks of cast-iron arranged alongside one another upon the shaft so as to form a massive cylinder which is wound about with stout copper wire. The inductive spools of

the ring are connected by means of screws with the phosphor-bronze plates of the commutator *C*. In this dynamo the current generated in the ring does not pass first through the electro-magnets,

Fig. 35.



and then as working current into the conductor, but the greater portion passes as working current from the brushes *B B* into the conductor to the baths, while the other comparatively smaller portion of current passes through the wrappings of the electro-magnets *M M*, and excites them. As in Schuckert's machines, a regulator with resistance coils may be inserted in the circuit of the current, which allows of the generation of the current being controlled within quite wide limits, as may be desired. The advantages of this dynamo consist in the large masses of iron of short length with a large cross-section of the cores of the electro-magnets, the standards and base being made in one piece, and the durable iron core of the ring; the formation of sparks is slight.

The Lahmeyer dynamo, shown in Figs. 36, 37, and 38, in cross-section, open side view, and perspective exterior view, fulfils the three principal conditions of a good dynamo, viz., great useful effect, discharge of the current without sparks, and solidity of construction. Opposite to the drum-anchor or drum-inductor of the machine stand horizontally two short and stout electro-magnet cores, whose ends averted from the anchor are connected by a thick

iron frame carried above and below around the windings. This electro-magnet frame is made of soft cast-iron in one piece with the base of the machine, so that no resistance is offered to the

Fig. 36.

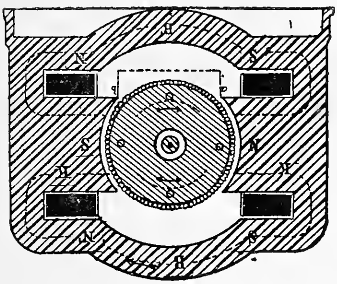
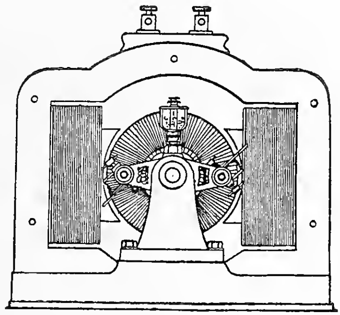


Fig. 37.



lines of force by a joint, while the large iron cross-sections also give rise to but slight magnetic resistance.

The magnetic field of the Lahmeyer machine must be considered as a magnetic circle in so far as the lines of force which are generated by the spools in the iron everywhere contiguous to them pass together through both spools, and only ramify outside of them in the re-conducting plates $B B'$. By this favorable disposition, a current of slight strength passing through the wrappings of the electro-magnets produces a strong excitation of the latter.

The anchor has the shape of the Siemens cylinder, but is composed of disks of thin, white sheet-iron insulated one from the other by paper. Several segments of vulcanized fibre, two of which form the face, serve for holding the wrappings of the anchor. The latter consists of a single layer of stout copper wire, and this, in conjunction with the symmetrical disposition which excludes the scattering of the lines of force as much as possible, effects a discharge of the current without sparks. The space visible in the side view is closed by perforated plates secured by screws, as seen in Fig. 38. This is a further advantage of the machine in so far that all sensitive parts are protected from external injury. Like all cylinder or drum dynamos, the Lahmeyer dynamo requires a large number of revolutions per minute, but

with the slight weight of the anchor, and the solid construction of the bearings, there is but little danger of the rapid wearing out of the latter.

Fig. 38.

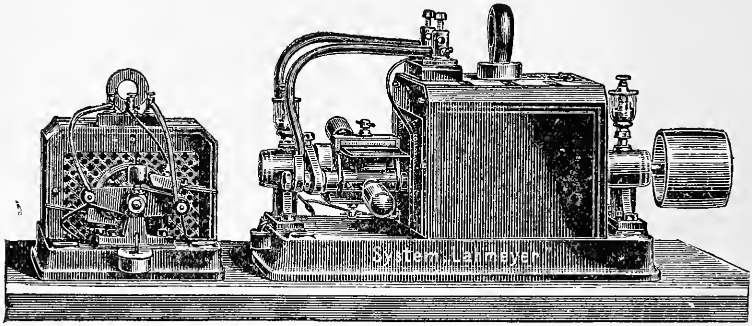
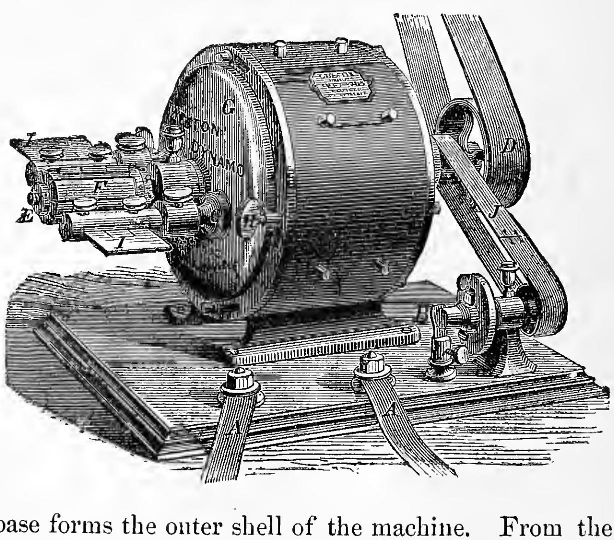


Fig. 39 represents the Weston machine, which is much used in this country. Being of small dimensions, of compact form, and yielding an abundant current, it is well adapted to the wants of the electro-plater. An iron ring or cylinder attached to an

Fig. 39.



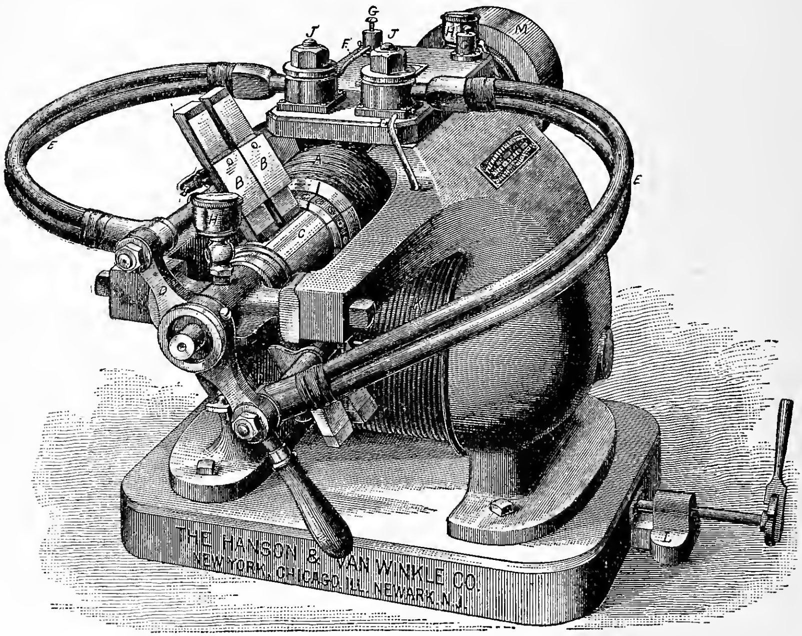
iron base forms the outer shell of the machine. From the interior of this cylinder, and projecting radially towards the centre

of the apparatus, are arranged a number of magnets (usually five), which consist of a core of iron to which are fastened a number of thin tempered steel plates, and they are wrapped with insulated copper wire and so connected that the poles shall be alternately north and south. In the central space left between the inward ends of these magnets is arranged a shaft carried by bearings, which, to secure greater strength and perfect alignment, are cast on the iron disks or heads which are accurately fitted and bolted to the ends of the cylinder. To the shaft is secured a series of armatures made in segments. The armatures are of iron and also wrapped with wire. When revolved the outwardly projecting ends of these armatures will pass closely to, but without touching, the inwardly projecting ends of the magnets. The commutator is made in two pieces, and requires but two springs to carry the currents from all the armatures. These springs or brushes are clamped in sockets projecting from the front disk of the cylinder. An automatic switch or governor is attached to this machine for the purpose of preventing it from reversing by the polarization of the electrodes.

The new dynamo electro-plating machine manufactured by the Hanson & Van Winkle Co., of Newark, New Jersey, is shown in Fig. 40. *K* is the coil of the field magnet, *A* the revolving armature, and *C* the commutator. *BB* are the brushes for picking up the currents of electricity produced in the armature by revolving in the magnetic field and causing them to flow in one direction. The current is not produced by friction. *D* is the lever to adjust the position of the brushes to the commutator. *NN* are $\frac{3}{8}$-inch copper rods from the machine to the tank or to the main conductors on the wall. The binding-post on the machine marked *P* is joined to rods connected with the anodes, while *N* is connected to the object rods. The rods on the tank should be kept bright with emery paper. When but one tank is used, make direct connection in the same way after getting the speed of the machine satisfactory for the maximum amount of work. The current may be decreased for small surfaces by moving the handle of the resistance board from the point marked "strong," one segment at a time, until it is found to answer. The position of the brushes, as shown in the cut, is the strongest point. By

moving to the right or left the current is diminished. A slight change of position of the brushes is sometimes an advantage in setting the brushes when running on large surfaces to avoid sparks.

Fig. 40.



In using the resistance boards, (see later on) they are put up as near the tank as possible—the weak point being used when putting work in the tank, and then the strength of current is increased until the power required is obtained.

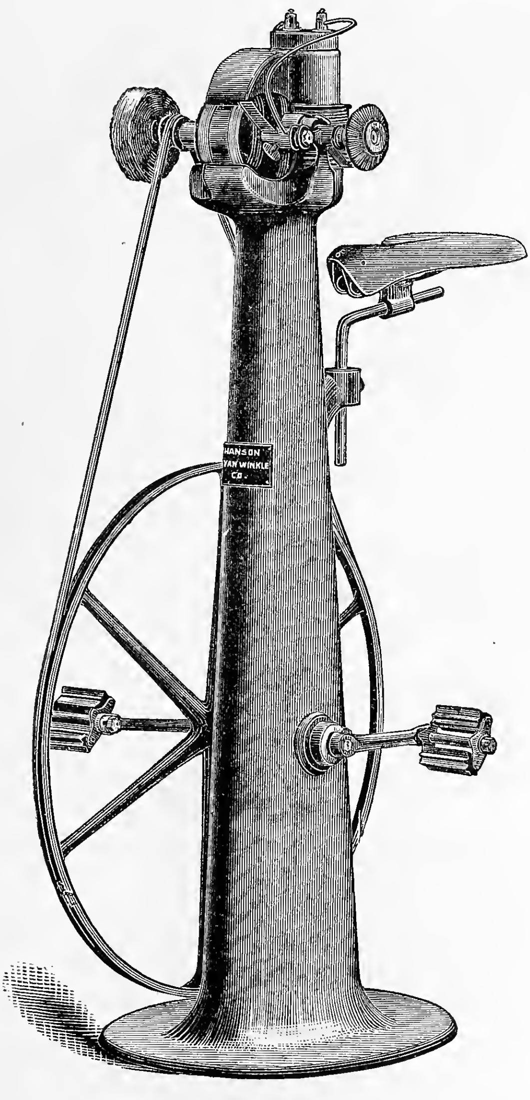
The proper current for nickel-plating on brass or other smooth surfaces, is when the gas is seen to adhere to the work, and there is no tendency to blacken edges.

The manufacturers of the above-described dynamo machine claim for it the following advantages:—

The field magnets have wrought-iron in them, vastly superior to cast-iron. The magnets have a round core, which, for a given amount of wire, is much more powerful. They have a very short

magnet-circuit. The commutator is easily taken off, so as to renew the segments, which are made of tempered copper, and are very durable. The armature and working parts are away from

Fig. 41.



the base, and are fully protected from dirt. The field magnets are wound on bobbins, and are easily replaced. The armature is of Norway iron, each piece being insulated from its neighbor and the steel shaft, which entirely dispenses with cross-currents and avoids heating of the armature core.

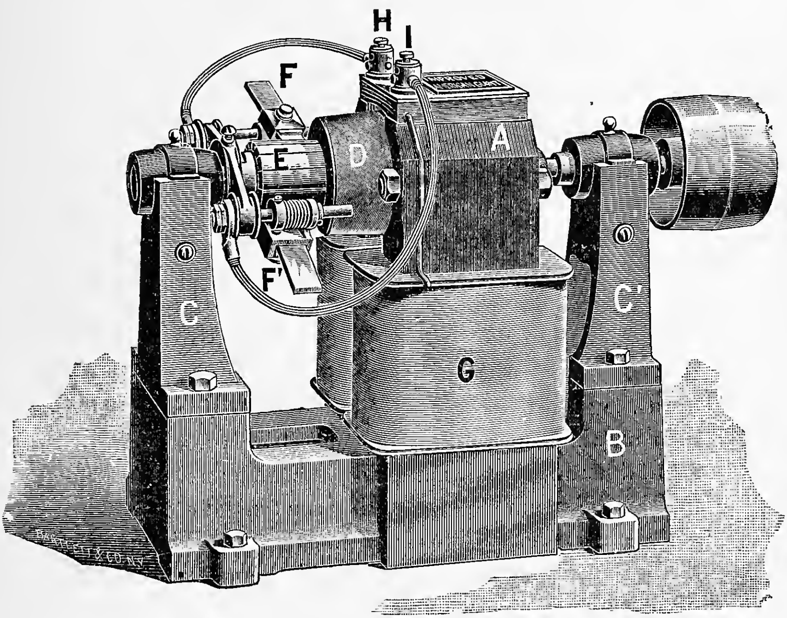
The same firm also manufactures the bicycle-power plating dynamo shown in Fig. 41. This dynamo is a regular machine, similar in construction and principle to the preceding larger machine. It consists of a dynamo cast upon an iron pedestal, with an arm extending for the support of the saddle and hubs in which the main bearing runs. The machine has direct poles, shortest possible magnetic circuit, and one field coil, giving greatest possible amount of magnetism in poles. The field-coil is wound upon a bobbin which can be readily taken off. The poles have extended arms, which, after being bored and boxed, turned to same diameter, and bolted into place, insures perfect alignment for bushings in which the armature shaft runs. Every part of the machine upon which wear comes is made in duplicate, and is easily exchanged for new parts. The machine has a regulation bicycle saddle with spring adjustments. The saddle post is adjustable, allowing a child or the tallest man to do the work with perfect satisfaction. The machine is provided with bearing rubber pedals, regulation bicycle cranks, and crank-pins.

This dynamo is intended for work on a small scale, serving as a substitute for the battery. With this machine the manufacturers claim that a dozen knives and forks can be plated with a triple coating of silver in twenty minutes. A large ice-pitcher can be plated in twenty-five minutes, and two dozen spoons in twenty minutes.

The "*Improved American Giant*" *Dynamo*, manufactured by the Zucker & Levett Chemical Company, of New York, is shown in Fig. 42. *A* is the field magnet, which is built of laminæ of the best Swedish iron in the smaller machines and of special cast-iron equal to wrought-iron in the larger machines. The laminæ are stamped out of one piece of iron, thus doing away with all joints and consequent magnetic leakage due to that cause. *B* is the base to which the field plates are bolted; *C* and *C′* are the

brackets which support the armature *D*. The bearings supported in the brackets are made of the hardest phosphor-bronze and are self-oiling. The armature is of an improved Siemens drum type, wound and connected so that the coils are perfectly balanced,

Fig. 42.



both mechanically and electrically, thus insuring an even distribution of electro-motive force.

The core of the armature is built of best Swedish iron, thoroughly insulated, to prevent Foucault or eddy currents and consequent heating. There is but one turn to every section, and each turn consists of a large number of strands of small wires, thus facilitating winding and obviating Foucault currents in the copper conductors. The heads are covered to prevent oil or dirt from entering.

The commutator having a large number of sections, a perfectly even current and deposit are obtained. The commutator-bars

are drop-forged copper thoroughly insulated with mica throughout.

F and *F'* are the brushes which collect the current. These brushes consist of a very large number of thin copper leaves, carefully filed to the proper level, and but a slight tension is required. This is easily adjusted with one thumb-screw on the brush-holder, which actuates a flat German silver spring, which increases or diminishes the tension.

G are the field magnet coils which are separately wound on iron spools with brass flanges, and then slipped over the cores. They are so wound as to prevent the dynamo from reversing, and have a comparatively high resistance, thus taking out little energy in combination with the extremely low resistance of armature. The absence of eddy currents, etc., makes this a most efficient machine.

Detailed descriptions of other machines such as the Müller, Mather, Elmore, Bürgin, Gülcher, etc., would needlessly lengthen this chapter. The great impulse which the art of electro-plating has within the past decade received is largely due to the great improvements that have within this period been made in the construction of dynamo-electric machines, by which mechanical energy generated by the steam-engine or other convenient source of power may be directly converted into electrical energy. Without dynamos it would be impossible to electro-plate large parts of machines, building ornaments, etc., which are thus protected from the influence of the weather. They may safely be credited with having called into existence an important branch of the electro-plating art, viz., nickel-plating, and especially the nickel-plating of zinc sheets as well as sheets of copper, brass, steel, and tin, which would have been impossible if the manufacturer had to rely upon the generation of the electric current by batteries. The latter, at the very best, are troublesome to manage; they only give out their full power when freshly charged, and as the chemical actions upon which they rely for their power progress, they deteriorate in strength and require frequent additions of acids and salts to be freshly charged, and their use demands constant vigilance and attention. Even when working on a small scale it is cheapest to

procure a small gas or other motor for driving a small dynamo, the lathes, and grinding and polishing machines.

To make it possible for the manufacturer of dynamos to suggest the most suitable machine, the following data should be submitted to him :—

1. Variety, size, and number of the baths which are to be fed by the machine.

2. The average surface of the articles in the bath, or their maximum surface, and the metals of which they consist.

3. Whether at one time many and at another time few articles are suspended in the bath.

4. The distance at which the machine can be placed from the baths.

5. The power at disposal.

IV.

PRACTICAL PART.

CHAPTER IV.

ARRANGEMENT OF ELECTRO-PLATING ESTABLISHMENTS IN GENERAL.

ALTHOUGH rules valid for all cases cannot be given, because modifications will be necessary according to the size and extent of the establishment, the nature of the articles to be electro-plated, and the method of the process itself, there are, nevertheless, certain main features which must be taken into consideration in arranging every establishment, be it large or small. Only rooms with sufficient light should be used, since the eye of the operator is severely taxed in judging whether the articles have been thoroughly freed from fat, in recognizing the different tones of color, etc. A northern exposure is especially suitable, since otherwise the reflection caused by the rays of the sun may exert a disturbing influence. For large establishments the room containing the baths should, besides side-lights, be provided with a sky-light, which, according to the location, is to be protected by curtains from the rays of the sun.

Due consideration must be given to the frequent renewal of the air in the rooms. Often it cannot be avoided that the operations of pickling, etc., must be carried on in the same room in which the baths are located. Especially unfavorable in this respect are smaller establishments working with batteries, in which the vapors evolved from the latter are added to the other vapors, and render the atmosphere injurious to health. Hence, if possible, rooms should be selected having windows on both sides, so that by opening them the air can at any time be renewed, or the baths and batteries should be placed in rooms provided with chimneys;

by cutting holes of sufficient size in the chimneys near the ceilings of the rooms the discharge of injurious vapors will in most cases be satisfactorily effected.

To those working with Bunsen elements, it is recommended to place them in a closet varnished with asphalt or ebonite lacquer, and provided with lock and key. The upper portion of the closet should communicate by means of a tight wooden flue with a chimney or the open air.

Since the baths work with greater difficulty, slower and more irregular below a certain temperature, provision for the sufficient heating of the operating rooms must be made. Except baths for hot gilding, platinizing, etc., the average temperature of the plating solutions should be from 64.5° to 68° F., at which they work best; it should never be below 59° F., for reasons to be explained later on. Hence, for large operating rooms such heating arrangements must be made that the temperature of the baths cannot fall below the minimum even during the night, otherwise provision for the ready restoration of the normal temperature at the commencement of the work in the morning has to be made. Rooms heated during the day with waste steam from the engine, generally so keep the baths during the winter—the only season of the year under consideration—that they show in the evening a temperature of 64.5° to 68° F., and if the room is not too much exposed, the temperature, especially of large baths, will only in rare cases be below 59° F. For greater security the heating pipes may be placed in the neighborhood of the baths; if this should not suffice to protect the baths from cooling off too much, it is advisable to locate in the operating room a steam conduit of small cross-section fed from the boiler and to pass steam for a few minutes through a coil of metal indifferent to the plating solution suspended in the bath. In this manner baths of 1000 quarts, which, on account of several days' interruption in the operation had cooled to 36° F., were in ten minutes heated to 68° F. For smaller baths it is better to bring a small portion of them in a suitable vessel to the boiling-point, over a gas flame, and adding it to the cold bath, and if, after mixing, the temperature of the bath is still too low, repeating the operation.

Another important factor for the operating rooms is the con-

venient renewal of the waters required for rinsing and cleansing. Without water the electro-deposition of metals is impossible; the success of the process depends in the first place on the careful cleansing of the metallic articles to be electro-plated, and for that purpose water, nay, much water, hot and cold, is required, as will be seen in the "preparation of the articles." Large establishments should, therefore, be provided with pipes for the admission and discharge of water, one conduit terminating as a rose over the table where the articles are freed from grease. In smaller establishments, where the introduction of a system of water-pipes would be too expensive, provision must be made for the frequent renewal of the cleansing water in the various vats.

In consequence of rinsing and transporting the wet articles to the baths much moisture collects upon the floor of the operating rooms. The best material for floors of large rooms is asphalt, it being, when moist, less slippery than cement; a pavement of brick or mosaic laid in cement is also suitable, but has the disadvantage of cooling very much. The pavement of asphalt or cement should have a slight inclination, a collecting basin being located at the lowest point, which also serves for the reception of the rinsing water. Wood floors cannot be recommended, at least for large establishments, since the constant moisture causes the wood to rot; however, where their use cannot be avoided, the places where water is most likely to collect, should be strewn with sand or saw-dust, frequently renewed, or the articles when taken from the rinsing water or bath be conveyed to the next operation in small wooden buckets or other suitable vessels.

The operating room should be of such a size as to permit the convenient execution of the necessary manipulations. Of course, no general rule can be laid down in this respect, as the size of the room required depends on the number of the processes to be executed in it, the size and number of articles to be electro-plated daily, or within a certain time, etc. However, there must be sufficient room for the batteries or dynamo, for the various baths, between which there should be a passage-way at least twenty inches wide, for the table where the articles are freed from grease, for the lye kettle, hot-water reservoir, saw-dust receptacle, tables for tying the articles to hooks, etc.

The rooms used for grinding, polishing, etc., also require a good light in order to enable the grinder to see whether the article is ground perfectly clean, and all the scratches from the first grinding are removed. Where iron or other hard metals are ground with emery, it is advisable to do the polishing in a room separated from the grinding shop by a close board partition, because in the preparatory grinding with emery, which is done dry, without the use of oil or tallow, the air is impregnated with fine particles of emery, which settle upon the polishing disks and materials, and in polishing soft metals cause fine scratches and fissures injurious to the appearance of the articles and difficult to remove by polishing. Hence, all operations requiring the use of emery, or coarse grinding powders, should be performed in the actual grinding-room, as well as the grinding upon stones and scratch-brushing by means of rapidly revolving steel scratch-brushes of iron castings. Articles already electro-plated are, of course, scratch-brushed in the plating-room itself, either on the table used for freeing the articles from grease, or on a bench especially provided for the purpose. In the polishing room are only placed the actual polishing machines, which by means of rapidly revolving disks of felt, flannel, etc., and the use of polishing powders, or polishing compositions, impart to the articles the final lustre before and after electro-plating. The formation of dust in the polishing rooms is generally over-estimated; it is, however, sufficiently serious to render their separation by a close partition from the electro-plaing room necessary, otherwise the polishing dust might settle upon the baths and give rise to various disturbing phenomena. In rooms in which large surfaces are polished with Vienna lime, as, for instance, nickelled sheets, the dust often seriously affects the health of the polishers, especially in badly ventilated rooms, and in such cases it is advisable to provide an effective ventilator. If this cannot be done, wooden frames covered with packing-cloth, placed opposite the polishing disks, render good service; the packing-cloth, by being frequently moistened, retaining a large portion of the polishing dust.

For grinding lathes requiring the belt to be thrown off in order to change the grinding, it is best to place the transmission carrying

the belt-pulleys at a distance of about three feet from the floor, for lathes with spindles outside the bearings the transmission may be on the ceiling or wall. The revolving direction of the principal transmission should be such as to render the crossing of the belts to the grinding and polishing machines unnecessary, otherwise the belts on account of the great speed will rapidly wear out.

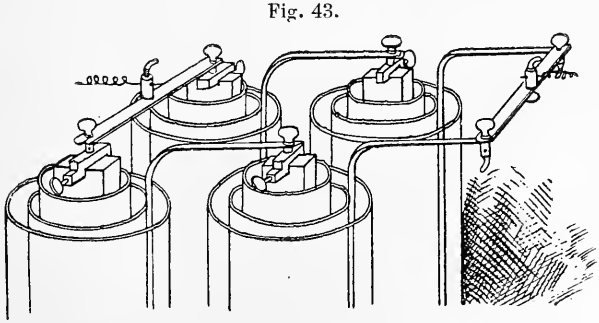
ELECTRO-PLATING ARRANGEMENTS IN PARTICULAR.

The actual electro-plating plant consists of the following parts: 1. *The sources of current* (batteries or dynamo-electric machines) *with auxiliary apparatus.* 2. *The current-conductors* 3. *The baths,* consisting of the vats, the plating solution, the anodes, and the conducting rods with their binding-screws. 4. *The apparatuses* for cleansing, rinsing, and drying. The sources of current have already been discussed in Chap. III. p. 29, and the laws governing the suitable coupling of the elements on p. 17.

A. *Arrangement with elements.*—In working with elements it is first necessary to have a clear idea of the area of the articles which are to be *at one time* electro-plated in a bath, and of the magnitude of the resistance opposed by the bath to the current. This and the size of the anodes show how many elements must be put together for a battery, and how the elements are to be coupled. Suppose we have a nickel bath which requires for its decomposition a current of 2.5 volts of electro-motive force or tension; now since, according to p. 36, a Bunsen element yields a current of 1.88 volts, the reduction of the nickel cannot be effected with one such element, but two elements must be coupled for tension one after the other, whereby, leaving the conducting resistance of the wires out of consideration, an electro-motive force or tension of $2 \times 1.88 = 3.76$ volts is obtained, with which the decomposition of the solution can be effected. If, on the other hand, we have a silver bath which requires only $\frac{1}{2}$ volt for its decomposition, we do not couple two elements one after the other, because the electro-motive force of a single element suffices for the reduction of the silver. On p. 17 it has been seen that by coupling the elements one after the other (coupling for tension) the electro-motive force of the battery

is increased, but the quantity of current is not increased, and that to attain the latter the elements must be coupled alongside of one another (coupled for quantity). Hence in a group of, for instance, three elements coupled one after another, only one single zinc surface of the elements can be considered effective in regard to the quantity of current. Now, the larger the area of articles at the same time suspended in the bath is, the greater the number of such effective zinc surfaces of the group of elements to be brought into action must be, and, if for baths with medium resistance, it may be laid down as a rule that the effective zinc surface must be at least as large as the area of the articles, provided the surface of the anodes is at least equal to the latter, the approximate number of elements and their coupling for a bath can be readily found. Let us take the nickel bath, which, as above mentioned, requires a current of 2.5 volts, and for the decomposition of which two elements must, therefore, be coupled one after the other, and suppose that the zinc surface of the Bunsen elements is 500 square centimetres, then the effective zinc surface of the two elements coupled one after the other will also be 500 square centimetres; hence a brass sheet $20 \times 25 = 500$ centimetres can be conveniently nickelled on one side with these two elements, or a sheet $10 \times 25 = 250$ centimetres on both sides. Now suppose the surface to be nickelled were twice as large, then the two elements would not

Fig. 43.



suffice, and a second group of two elements, coupled one after the other, would have to be joined to the first group for quantity as shown in Fig. 4, or perspectively in Fig. 43. Three times the object surface would require three groups of elements, and so on.

In giving these illustrations it is supposed the objects are to have a thick solid plating; for rapid plating with a thin deposit a different course has to be followed. Only a slight excess of electro-motive force in proportion to the resistance of the bath being in the above-mentioned case present, reduction takes place slowly and uniformly without violent evolution of gas on the objects, and by the process thus conducted the deposit formed is sure to be homogeneous and dense, since it absorbs but slight quantities of hydrogen, and in most cases it can be obtained of sufficient thickness to be thoroughly resistant. If, however, the operation is to be executed quickly and without regard to great solidity and thickness of the deposit, the elements have to be coupled so that the electro-motive force is sufficiently large for the current to readily overcome the resistance of the bath. This is attained by coupling three, four, or more elements one after the other, as shown in the scheme Fig. 2. However, such deposits can never be homogeneous, because they condense and retain relatively large quantities of hydrogen.

As regards the filling and other management of the batteries, the reader is referred to pp. 34–39, under Bunsen elements. Having seen how many elements are required, and how they have to be coupled to form a battery for certain purposes, we will next consider the *auxiliary apparatuses.*

Only in very rare cases will it be possible to always charge a bath or several baths with the same object-area; and according to the amount of business, or the preparation of the objects by grinding, polishing, and pickling, at one time large, and at another small, areas will be suspended in the bath. Now, suppose a battery suitable for a correct deposit upon an area of, say five square feet, has been grouped together; and, after emptying the bath, a charge only half as large is introduced, the current of the battery will, of course, be too strong for this reduced area, and there will be danger of the deposit not being homogeneous and dense, but forming with a crystalline structure, the consequence of which, in most cases, will be slight adhesiveness, if not absolute uselessness. With sufficient attention the total spoiling of the articles might be prevented by removing the objects more quickly from the bath. But this is groping in the dark, the objects being either taken too

soon from the bath, when not sufficiently plated, or too late, when the deposit already shows the consequences of too strong a current.

To control the current an instrument called the *rheostat, current-regulator, resistance board,* or *switch board,* has been constructed, which allows of the current-strength of a battery being reduced without the necessity of uncoupling elements. It is evident that the current of a battery, if too strong, can be weakened by decreasing the number of elements forming the battery, and also by decreasing the surface of the anodes, because the external resistance is thereby increased. This coupling and uncoupling of elements is, however, not only a time-consuming, but also a disagreeable labor; and it is best to use a resistance board, with which by the turn of a handle, the desired end is attained. Figs. 44 and 45 show this instrument. Its action is based upon the

Fig. 44.

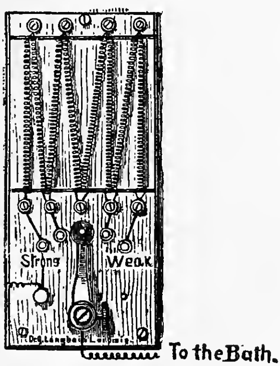
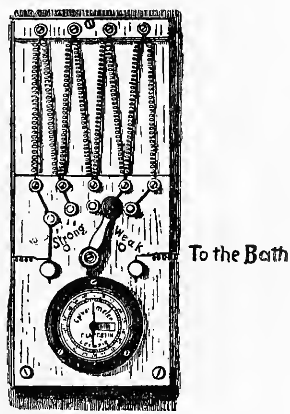


Fig. 45.



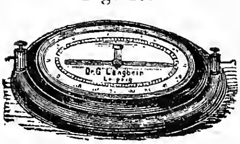
following conditions: As explained on p. 19, the maximum performance of a battery takes place when the external resistance is equal to the internal resistance of the battery. By increasing the external resistance, the performance is decreased, and a current of less intensity will pass into the bath when resistances are placed in the circuit. The longer and thinner the conducting wire is, and the less conducting power it possesses, the greater will be the resistance which it opposes to the current. Hence, the resistance board consists of metallic spirals which lengthen the circuit, con-

tract it by a smaller cross-section, and by the nature of the metallic wire have a resistance-producing effect. For a slight reduction of the current, copper spirals of various cross-sections are taken, which are succeeded by brass spirals, and finally by German silver spirals, whose resistance is eleven times greater than that of copper spirals of the same length and cross-section. In Fig. 44 the conducting wire coming from the battery goes to the screw on the left side of the resistance board, which is connected by stout copper wire with the first contact-button on the left; hence by placing the metallic handle upon the button furthest to the left, the current passes the handle without being reduced, and flows off through the conducting wire secured in the setting-screw of the handle. By placing the handle upon the next contact-button, to the right, two copper spirals are brought into the circuit; by turning the handle to the next button four spirals are brought into the circuit, and so on. By a choice of the cross-sections of the spirals, their length and the metal of which they are made, the current may be more or less reduced as desired.

To control the reduction of the current effected by the resistance, a galvanometer is placed behind it. It consists of a magnetic needle oscillating upon a pin, below which the current is conducted through a strip of copper, or, with weaker currents, through several coils of wire. The electric current deflects the magnetic needle from its position, and the more so the stronger the current is; hence the current-strength of the battery can be determined by the greater or smaller deflection.

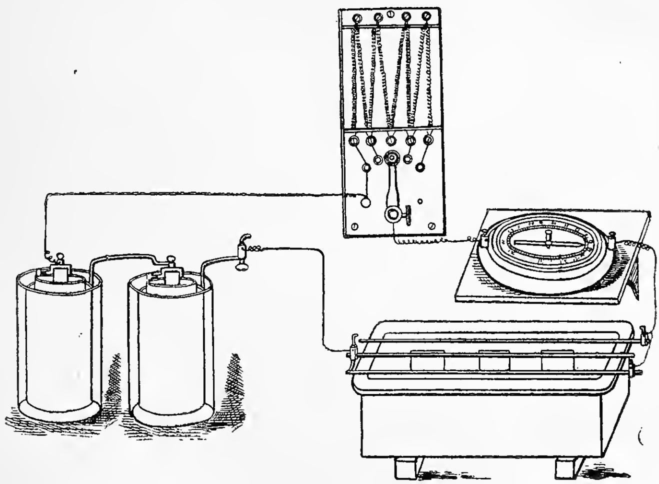
For a weak current, such as, for instance, that yielded by two elements, it is of advantage to use a horizontal galvanometer (Fig. 46). It is screwed to a table by means of a few brass screws in such a position that the needle in the north position, which it occupies, points to 0° when no current passes through the instrument. Articles of iron and steel must, of course, be kept away from the instrument. For stronger currents, it is better to combine a vertical galvanometer with the resistance board and fasten it to the same frame as shown in Fig. 45. The screw of the handle of the resistance board is connected

Fig. 46.



with one end of the copper strip of the vertical galvanometer, while the other is connected with the screw on the right side of the resistance board in which is secured the wire leading to the bath. The resistance board and galvanometer are placed in one conducting wire only, either in that of the anodes or of the objects; one of these wires is simply cut, and the end connected to the battery is secured in the setting-screw on the side of the resistance board marked "strong," while the other end which is in connection with the bath is secured in the setting-screw on the opposite side marked "weak." The entire arrangement will be perfectly understood from Figs. 47 and 50.

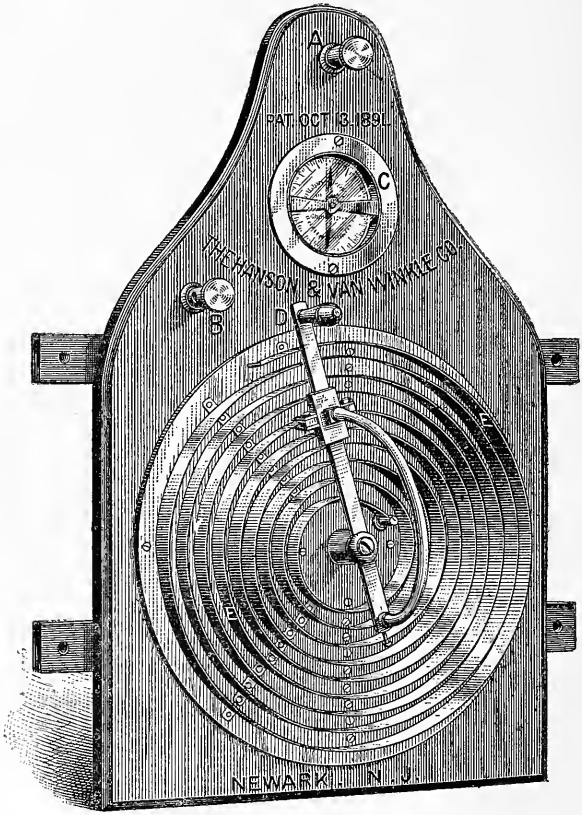
Fig. 47.



Figs. 48 and 49 show two rheostats patented and manufactured by the Hanson & Van Winkle Company, of Newark, N. J. In Fig. 48, the spiral *EE* is a ribbon of German silver of various thicknesses depending on the size of dynamo or size of tank. When the lever *D* is moved to the right, the contact-piece in connection with a flexible covered copper cable is moved towards the centre or point of maximum power. When this is moved to the left, there is an increase of resistance until the end of the spiral is reached. The position of the contact-piece is shown midway. As will be seen, the movement is under perfect control, and is con-

tinuous without any sudden fluctuation of power. The connection A is connected with rod to one pole of the dynamo, and connection B to the anode rod of the tank. C is the galvanometer.

Fig. 48.

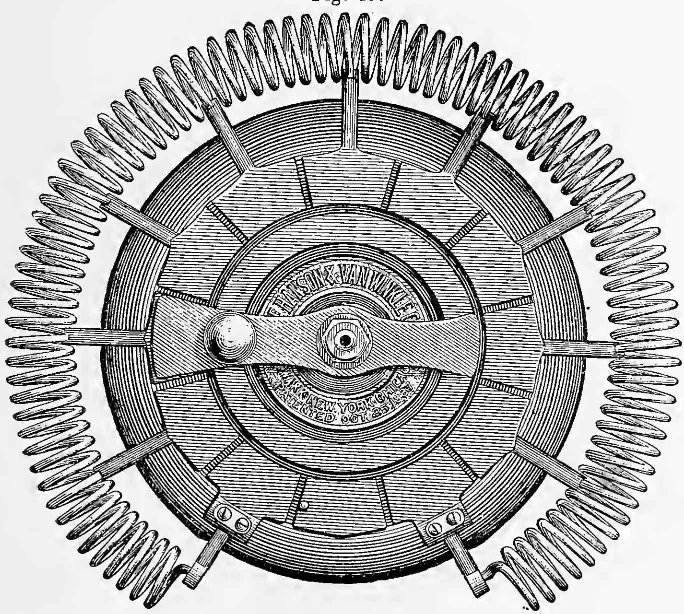


An improved rheostat shown in Fig. 49 is adapted for the smallest currents and tanks up to the largest currents and surfaces. It is manufactured by the same firm.

As is well known, different voltages are employed to operate different solutions. It is required of the electro-plating dynamo that a voltage sufficiently great be generated to do the work in a solution that is of the highest resistance, and at the same time deposit in low resistance solutions. Then again the voltage has

to be great enough to overcome the resistance of the conductors to the various tanks, which frequently is unnecessarily great. The tank nearest the dynamo, with the customary method, receives the most current, and a tendency to burn and blacken is noticed in a marked degree. When metals such as silver and copper are to be deposited in connection with such metals as nickel and brass, requiring a higher electro-motive force, a considerable drop in voltage is demanded in the lower resistance solutions, so as not to blacken the work. With the ordinary style of resistance board, this is done at a great loss of current and work capacity of tank.

Fig. 49.



When a tank is being filled with work, with the improved rheostat in circuit, the current can be entirely cut off, or partially left on, as may be desired. When the tank is full the current can be switched on, and with this rheostat sufficient current may be conveyed to the work in the fastest manner. With old resistance boards about the greatest carrying capacity that they will feed is from 25 to 35 ampères, and never over 35 ampères, the reason for this deficiency being the smallness of the resistance

wire, insufficient metal-conductivity, combustible material for backing, etc. It is necessary to have some resistance in the circuit, so as not to blacken the work. With the improved rheostat, three times the current can be conveyed without showing heat in the least, in any part of the same, the resistance-wires, segments, switch or base-plate.

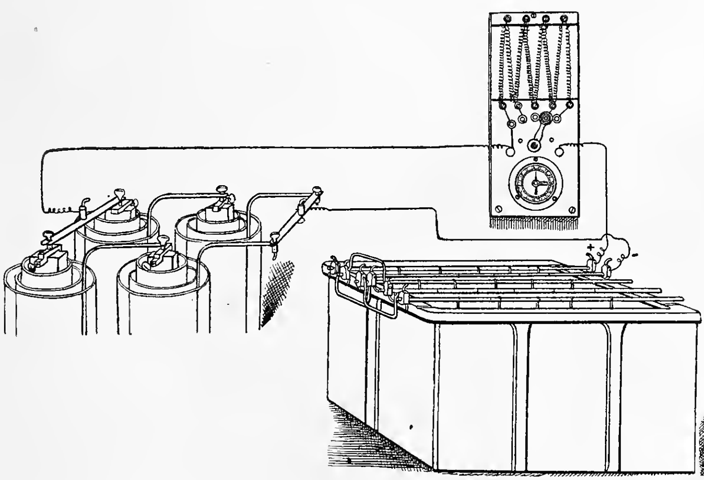
If, with the old style of resistance boards, more than 35 ampères are to be carried, the wire gets too hot, warps out of shape, and burns out the back or base-board, which is of wood or other combustible material, blues over and melts out segments, etc. With the improved rheostat all this is overcome, it being constructed upon scientific principles, with large heavy copper segments having great carrying capacity, with a most solid switch held against segments, with heavy, strong spiral springs, firmly held down with two nuts, all mounted upon a cast-iron base-plate, insulated entirely with non-combustible material.

This rheostat is claimed by the manufacturers to have twice the carrying capacity of any resistance board ever made for this purpose, it having at the same time sufficient length of wire to allow of toning down the highest electro-motive force used in electro-plating to the lowest degree that is ever called for, without showing heat or any unfavorable symptoms. It is further claimed that by the use of this rheostat any plating-room using two or more tanks can be doubled in capacity, provided the dynamo has the current-capacity. The old-style boards have, as a rule, plenty of resistance for small work, but not the carrying capacity to allow sufficient ampères to pass to do the work that a tank is capable of.

This improved rheostat is manufactured in various sizes and capacities (Nos. 1 to 7) by the Hanson & Van Winkle Co., of Newark, N. J., at prices varying from $10 to $40. Nos. 1, 2, and 3 are suitable for controlling the shunt-field of the dynamos manufactured by the same firm, also for small tanks; No. 4 is suitable for controlling large dynamos in their shunt, and medium-size tanks; No. 5 is suitable for controlling the ordinary size tanks that are in most general use; No. 6 is suitable for extra large size tanks, and No. 7 for controlling main line currents and groups of tanks.

Having discussed the advantages derived from the use of the resistance board, it remains to add a few words regarding the indications made by the galvanometer. Since the greater deflection of the needle depends, on the one hand, on the greater current-strength, and, on the other, on the slighter resistance of the outer closing arc (conducting wires, baths, and anodes), it is evident that a bath with slighter resistance, when worked with the same battery and containing the same area of anodes and objects, will cause the needle to deflect more than a bath of greater resistance under otherwise equal conditions. Hence the deductions drawn from the position of the needle for the electro-plating process are valid only for determined baths and determined equal conditions, but with due consideration of these conditions are of great value. Suppose a nickel bath always works with the same area of objects

Fig. 50.



and of anodes, and experiments have shown that the suitable current-strength for nickelling this area of objects is that at which the needle stands at 15° ; and suppose further that the battery has been freshly filled and causes the needle to deflect to 25°, then the handle of the resistance board will have to be turned so far to the right that the needle, in consequence of the introduced resistances, returns to 15°. Now if, after working for some time,

the battery yields a weaker current, the needle, since the resistance remains the same, will constantly retrograde, and has to be brought back to 15° by turning the handle to the left, when a current of equal strength of the former will again flow into the bath. This play is repeated until finally the handle stands upon the button furthest to the left, at which position the current flows directly into the bath without being influenced by the resistances of the resistance board. If now the needle retrogrades below 15°, it is an indication to the operator that he must renew the filling of the battery if he does not prefer suspending fewer objects in the bath. For this reduced object-area it is no longer required for the needle to stand at 15° in order to warrant a correct progress of the galvanic process, since the resistance being in this case greater, a deflection to 10°, or still less may suffice. This illustration will sufficiently show that the current-indication by the galvanometer is not and cannot be absolute, but that the deductions must always be drawn with due consideration to the conditions—area of objects and of anodes, and distance between them. An operator to be sure in this respect, and, above all, wishing to work scientifically, will replace the galvanometer by a voltmeter, which indicates the absolute magnitude of the electro-motive force passing into the bath, as will be explained later on.

It frequently happens that in consequence of defective contacts with the binding-screws of the battery, or by the conductors of the objects and of the anodes touching one another (short circuit with non-insulated conducting wires), no current whatever flows into the bath. Such an occurrence is immediately indicated by the galvanometer, the needle being not at all deflected in the first case, while in the latter the deflection will be entirely different from the usual one. The magnetic needle of the galvanometer also furnishes a means of recognizing the polarity of the current. If the galvanometer be placed in the positive conductor by securing the wire coming from the battery in the binding-screw on the south pole of the galvanometer, and the wire leading to the bath in the binding-screw on the north pole of the needle, the needle, according to Ampère's law, will be deflected in the direction of the hands of a watch, *i. e.*, to the right if the observer stands so in front of the galvanometer as to look from the south pole

towards the north pole, because the battery current flows out from the positive pole through the conducting wire, anodes, and fluid to the objects, and from these back through the object wire to the negative pole of the battery. If now in consequence of the counter-current formed in the bath by the metallic surfaces of dissimilar nature (see later on), and flowing in an opposite direction to that of the battery-current, the latter is weakened, the needle will constantly further retrograde from the zero point, and when the counter or polarizing current becomes stronger than the battery-current, it will be deflected in an opposite direction as before. Hence, by observing the galvanometer the operator can avoid the annoying consequences of polarization, which will be further discussed under nickelling.

From what has been said in this chapter and in the theoretical part, it is self-evident what rules have to be observed in conducting the current. Since the current-strength is weakened by resistance, the cross-section of the current-carrying wire as well as of that leading to the objects and to the anodes must be of a size corresponding to the current-strength, and the material for the wires should possess as high a conducting power as possible. Chemically pure copper is best suited for this purpose. Some information for calculating the thickness of the wires will be found at the end of the section "Arrangement with dynamo machines."

The *positive* or *anode* wire effects the connection between the anodes of the bath and the positive pole (anode or carbon pole) of the battery, while the *negative* or *object wire* brings the objects in the bath into metallic contact with the negative (zinc) pole of the battery. As previously mentioned, the resistance board with galvanometer is placed in one or the other of the wires.

For conducting the electric current to the baths, metallic wires, bands, spirals, or ribbons are used. The conducting wires are either employed in their natural metallic state, or are covered with some insulating or poorly conducting substance, such as cotton, silk, India-rubber, gutta-percha, and various varnishes. It is evident that covered wires should be bare and clean at their extremities where they are connected with the battery and with the anodes and objects to be plated. Wires of pure, well-annealed copper possess the best conducting power, and should have a sec-

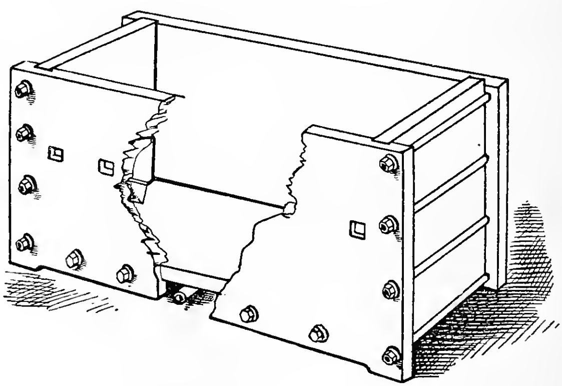
tional area capable of carrying the maximum quantity of current without offering appreciable resistance. Cables should be chosen where a large volume of current must be carried, they being more flexible than wire of a large size, and can be more easily laid.

Insulated wires may come in contact with each other without inconvenience. Such, however, is not the case with bare wires; because the electricity will pass through the shortest circuit and will not go through the bath if the two wires are in metallic contact. Such contact should, therefore be carefully avoided.

Vats or tanks.—These are the vessels to hold the plating solutions. Their shape may be either circular, square, or rectangular. They should be perfectly tight, impervious to the solutions, and unacted upon by them. They are made of different materials—stoneware, glass, or porcelain vats being best, but they are the most fragile and expensive.

Wooden vats must be carefully constructed, and are best secured at the ends by bolts and nuts, as shown in Fig. 51, which serve to hold the sides firmly against the end pieces. The vat is then

Fig. 51.



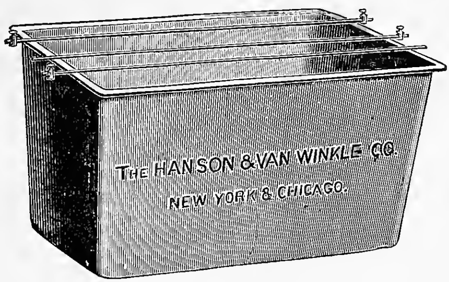
coated with a mixture of equal parts of pitch and rosin boiled with a small quantity of linseed oil. Another mixture, which has been found to afford a good protective covering to wood, consists of 10 parts of gutta-percha, 3 of pitch, and $1\frac{1}{2}$ each of stearin and linseed oil, melted together and incorporated.

For large baths containing potassium cyanide holders of bricks

laid in cement may also be used, or holders of boiler-plate lined inside with a layer of cement.

As an all-round useful vat there is nothing equal to one of enamelled iron such as is shown in Fig. 52. It is enamelled with a white acid-proof enamel and is highly recommended for all solu-

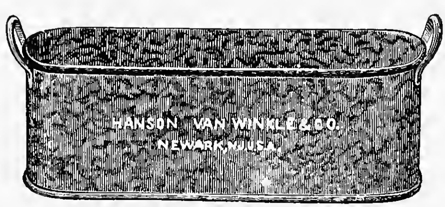
Fig. 52.



tions. It is made in other shapes and sizes up to $5\frac{1}{2}$ feet long, 24 inches wide, and 19 inches deep, and can be obtained from the Hanson & Van Winkle Company, of Newark, N. J., and other dealers in electro-plating materials.

Fig. 53 shows an agate vessel for gold and other solutions. This material stands cyanide solutions, acids, etc.

Fig. 53.



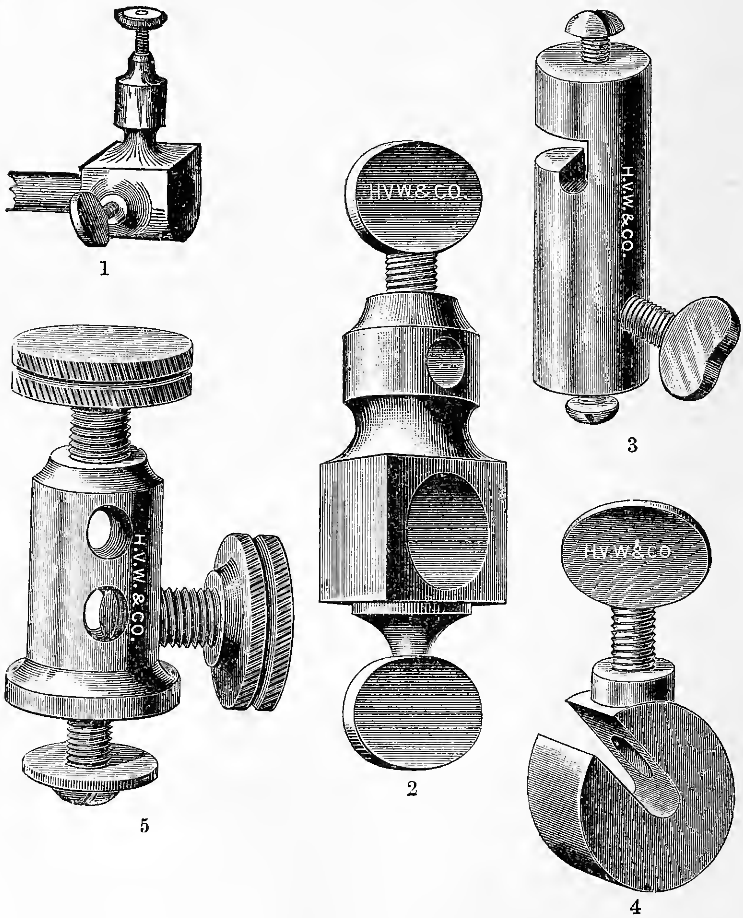
The vats for heating baths are best made of enamelled iron or wood lined with sheet lead; stoneware vats do not bear heating.

It is advantageous to provide the narrow sides of the vats with semi-circular notches for the conducting rods to rest in to prevent their rolling away. When using stoneware vats the conducting rods are laid directly upon the vats; vats of other material must be provided with an insulated rim of wood, or the rods are insu-

lated by pushing a piece of rubber hose over their ends. According to the size of the bath, 3, 5, 7, or more conducting rods, best of pure massive copper, are used.

To secure the uniform coating of the objects with metal they must be surrounded as much as possible by anodes, *i. e.*, the positive pole plates of the metal which is to be deposited. For

Fig. 54.



flat objects it suffices to suspend them between two parallel rows of anodes, the most common arrangement being to place three rods

across the bath, the two outermost of which carry the anodes, while the objects are secured to the centre rod. For wide baths five conducting rods are frequently used, but they should always be so arranged that a row of objects is between two rows of anodes. The arrangement frequently seen with four rods across the baths, of which the outermost carry anodes, and the other two objects, is irrational if the objects are to be uniformly plated on all sides, because the sides turned towards the anodes are coated more strongly than those suspended opposite to the other row of objects.

For large round objects it is better to entirely surround them with anodes, if it is not preferred to turn them frequently, so that all sides and portions gradually feel the effect of the immediate neighborhood of the anodes. (See "Nickelling.")

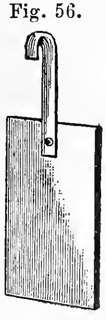
For objects to be plated on one side only the centre rod may be used for the anodes, and the two outer ones for the objects; the surface to be plated being, of course, turned towards the anodes.

The rods carrying the anodes, as well as those carrying the objects, must be well connected with each other, which is effected by means of binding posts and screws of the forms shown in Fig. 54, Nos. 1 and 2 being rod connections for tanks; No. 3 a wire connection for cutting-in branch between batteries or dynamos and tanks; No. 4, wire connection for two or more wires, and No. 5, binding-post for resistance board or dynamo.

The anodes are suspended from the cross rods by strong hooks of the same metal, so that they can be entirely immersed in the bath (Fig. 55); hooks of another soluble metal would contaminate the bath by dissolving in it, and this must be strictly avoided, as it would cause all sorts of disturbances in the correct working of the bath. In case hooks of another metal, except platinum, are used, the anodes must be hung so that they project above the surface of the liquid, and the hooks not being immersed are, therefore, not liable to corrosion; but the anodes are

Fig. 55.

Fig. 56.



then not completely used up, the portion dipping into the solution being gradually dissolved, whilst the portion projecting above the fluid remains intact. Instead of wire hooks, strips of the same metal as the anodes and fastened to them by a rivet may also be used (Fig. 56).

For suspending the objects lengths of soft pure copper wire, technically called *slinging wires*, are used. They are simply suitable lengths of copper wire of a gauge to suit the work in hand, wire of No. 20 Birmingham wire gauge (see Chapter XVIII., "Useful Tables") being generally employed for such light work as spoons, forks, and table utensils. Wire of a larger diameter should be employed for large and heavy goods. The immersed ends of these wires becoming coated with the metal which is being deposited, they should be carefully set aside each time after use, and when the deposit gets thick it should be stripped off in stripping acid, and the wire afterwards annealed and straightened for future use.

To keep the rods clean and to protect them from the fluid draining off from the articles when taken from the bath, it is advisable to cover them with a roof of strips of wood (/\ ), or a semicircular strip of zinc coated with ebonite lacquer; by this means the frequent scouring of the rods, which otherwise is necessary in order to secure a good contact with the hooks of the anodes, is done away with.

The plating solutions, briefly called baths, will be especially discussed in speaking of the various electro-plating processes. It still remains to consider the cleansing and rinsing apparatuses. Every electro-plating establishment, no matter how small, requires at least one tub or vat in which the objects can be rubbed or brushed with a suitable agent in order to free them from grease. This is generally done by placing a small kettle or stoneware pot containing the cleansing material at the right-hand side of the operator alongside the vat or tub. Across the latter, which is half filled with water, is laid a board of soft wood covered with cloth, which serves as a rest for the objects previously tied to wires. The objects are then scrubbed with a brush or rubbed with a piece of cloth dipped in the cleansing agent. The latter is then removed by rinsing the objects in the

water in the tub and drawing them through water in another tub. By this cleansing process a thin film of oxide is formed upon the metals, which would be an impediment to the intimate union ot the electro-deposit with the basis-metal. This film of oxide has to be removed by *dipping* or *pickling,* for which purpose another vat or tub containing the *pickle,* the composition of which varies according to the nature of the metal, has to be provided. After dipping, the objects have to be again thoroughly rinsed in water to free them from adhering pickle, so that for the preparatory cleansing processes three vessels with water, which has to be frequently renewed, as well as the necessary pots for pickling solutions, have to be provided. In case the vat for cleansing the articles or the box-like table (see Fig. 62) is provided with a rose-jet, under which the objects are rinsed, the other vats are not required.

After having received the electro-deposit the objects have to be again rinsed in cold water, which can be done in one of the three vats or with the rose-jet, and finally have to be immersed in hot water until they have acquired the temperature of the latter. How the water is heated makes no difference, and depends on the size of the establishment. The heated objects are then immediately dried in a box filled with dry, fine sawdust—that of maple, poplar, or other wood free from tannin being suitable for the purpose.

B. *Arrangements with dynamo-electric machines.*—For setting up and running the machines the following rules are to be observed. Larger machines are to be screwed to square wooden joists resting upon a solid brick foundation about six inches above the floor; smaller machines may be placed upon and fastened to strong tables secured to the floor or wall. The principal point is that the foundation or table is not subjected to shocks which would be transferred to the machines and cause, by the vibration of the brushes, a larger formation of sparks, and consequent greater wear of certain portions of the machine. Foundations about 8 inches wider on each side than the machine and built of brick and cement have been found most suitable. If possible, the machines should be located in the neighborhood of the baths they are to feed, since the greater the distance from the bath at which they are placed the larger the cross-section of the principal conducting

wire must be, and the more troublesome the regulation of the current will prove, provided it is not intended to place another resistance board just in front of the bath, which is the best plan for regulating the current with the greatest nicety.

It is best to set the dynamo in motion by means of a gearing with loose and fast pulley so as to render a gentle engaging of the machine possible, and not directly from the fly-wheel of the motor, whereby in consequence of the jumping and dragging of the belt it is apt to run less regularly. The bearings should be kept well lubricated, best with automatic oilers filled with good lubricating oil. The stated number of revolutions per minute should not be exceeded, since by the stronger current thereby generated the machine might become very hot and suffer injury. On the other hand, when a weaker current is required, the machine may be run more slowly than the maximum performance with the prescribed number of revolutions. The brushes which conduct the current from the commutator should be firmly secured in their holders by means of screws, and the levers pressing them by means of spiral springs against the commutators must be fixed so that the brushes securely and uniformly slide upon them; pressing the brushes too tightly against the commutators should, however, be avoided. While the machine is running the brushes should not be lifted off, since the large sparks thereby produced strongly attack the brushes and the commutator, and this favorite amusement of the workmen should be strictly forbidden.

When the machine is for the first time set in motion, the commutator should be gone over with a smooth file or emery paper to remove any projections of the insulation between the metallic plates, which readily swell when the machine stands in a damp place. The commutator should also daily be freed, by wiping, from copper-dust, and if after some time it wears unevenly be made smooth with a file.

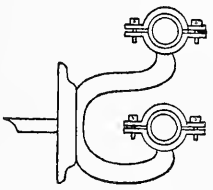
The inductor-ring should at least once every week be cleaned from copper-dust by means of a small bellows or other instrument. Movable articles of iron and steel should be kept away from the machine when running, as they might be attracted by the portions of the machine which have become strongly magnetic.

The object- and anode-wires must be insulated from each other,

as well as from the ground and damp brick-work by dry wood or porcelain, and the places of junction kept bright.

The employment of special wire-carriers, of the form shown in Fig 57, is advisable. They consist of cast-iron arms, provided on the ends with a case, between the lower and upper cover of which are disks of hard rubber.

Fig. 57.



To regulate the current resistance boards or current-regulators are used. They are constructed according to the same principles as those described under "Arrangement with Elements" (p .76), only the spirals are longer and of a larger cross-section, and the entire instrument is stronger. Instead of upon wood, the contact buttons are mounted upon slate plates, as wood would be carbonized by the spirals becoming hot.

In case one machine has to feed several baths of dissimilar nature and composition, the regulation of the current for all the baths in the main conducting wire is not feasible on account of the different resistances; and it will be necessary to place a resistance board in front of every bath. With dynamos of the Schuckert and Lahmeyer type, which are very practical, it will be further necessary to place a resistance board (the resistance board of the dynamo) in the windings of the machine, in order to be enabled to generate more or less current, as may be required, and to avoid an unnecessary consumption of power. From the scheme Fig. 58, for such a machine, with its auxiliary apparatus, the main conducting wire and a few baths, the reader will readily see what is required.

The dynamo resistance board will have to be placed so that the machine yields somewhat more current than with due consideration to the object-area is required for all the baths, while the supply of current for each bath is regulated by the resistance board placed in front of it. In the scheme Fig. 58 are sketched two further instruments for measuring the quantity and the electro-motive force of the current; by the first, called the *ampèremeter*, or better *ammeter*, the whole current-strength can be directly read off in ampères; and by the other, called the *volt-*

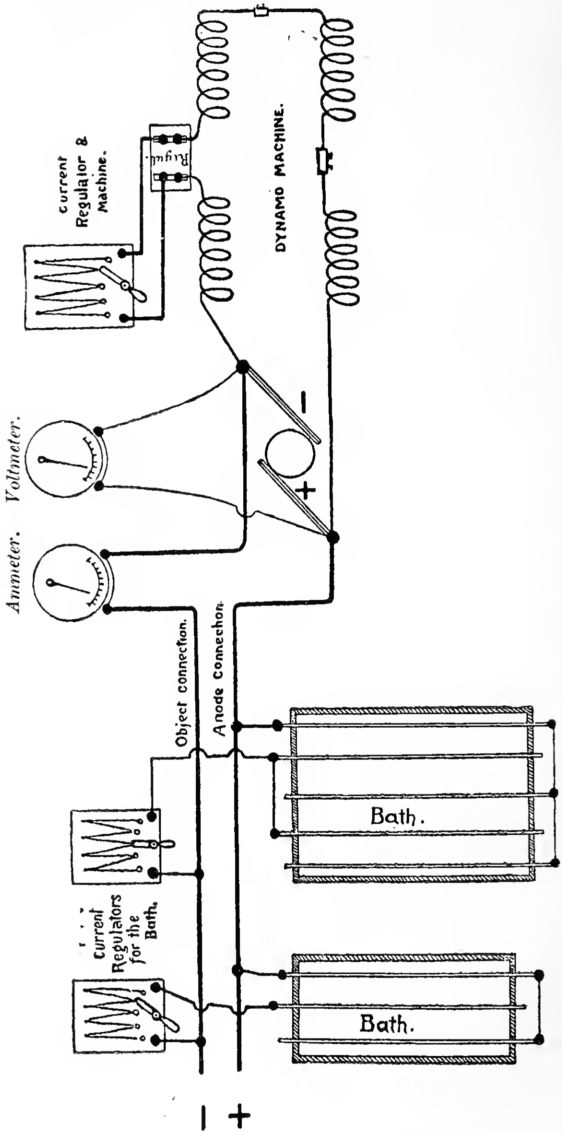
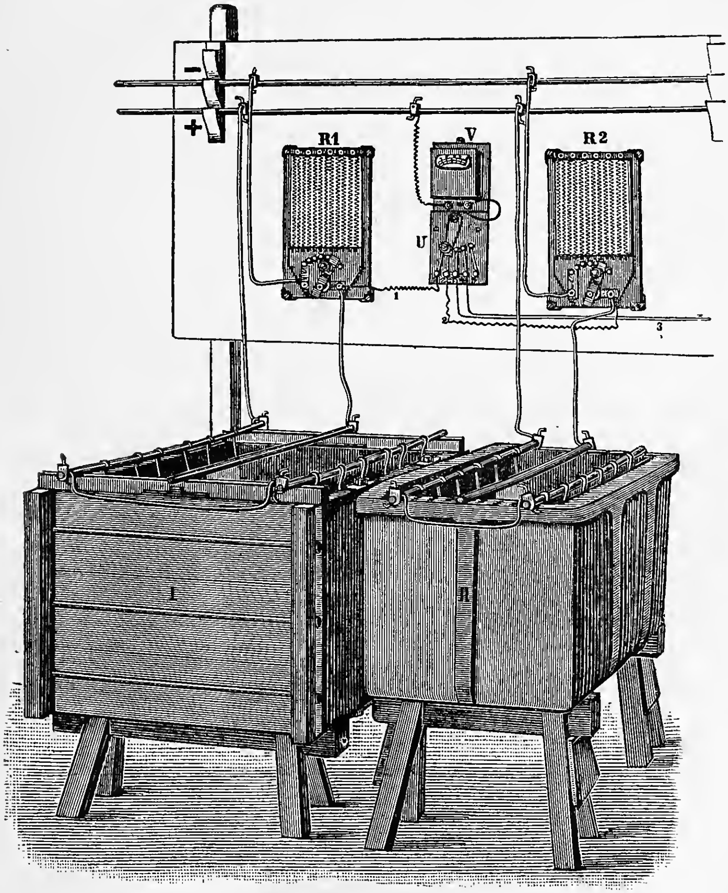


Fig. 58.

meter, the electro-motive force or tension in volts. The ampère-meter is placed in one conducting wire only, either in that of the object or of the anodes, while the voltmeter is connected with

both, one setting-screw being joined, on the points where the tension is to be measured, to the object-wire by a 0.039-inch thick copper wire, and the other to the anode wire. In the sketch (Fig. 58), the voltmeter being directly in contact with the poles of the machine will indicate the tension produced by it. This mode of placing the measuring instruments is, however, not suit-

Fig. 59.



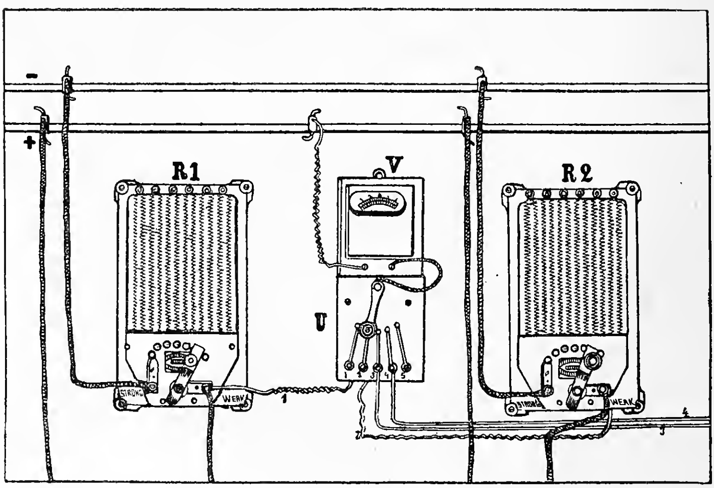
able for establishments using baths of different compositions and different resistances; in such case the tension must be measured

on the bath itself, and consequently the voltmeter has to be placed in the conducting wire between the resistance board of each bath and the bath itself. However, for a large establishment, using many baths, it would be quite an item of expense to provide each bath with a special voltmeter. But this is not necessary, one voltmeter sufficing for three, four, or even more baths. In order conveniently to read off on the voltmeter the tension of the current passing into one of these baths a *shunt* is required, the construction of which is seen from Figs. 59 and 60.

Fig. 59 shows the coupling of the main object-wire (—) and the main anode-wire (+), with the resistance boards R_1 and R_2, the voltmeter V, the shunt U, and the two baths.

In Fig. 60 the coupling is enlarged, and upon this the following description is based: Suppose the main object-wire and anode-wire to be connected with the corresponding poles of a

Fig. 60.



dynamo-machine or a battery, which for the sake of a clearer view is omitted in the illustration. The shunt U consists of a brass handle, mounted with a brass foot, upon a board; in the foot is a screw, with which is connected by a 0.039-inch thick copper-wire one of the pole-screws of the voltmeter. The brass handle drags with spring pressure upon contact buttons connected

by copper wire with the setting screws 1, 2, 3, 4, 5 (upon the shunt board), which serve for the reception of the 0.039-inch thick insulated wires 1, 2, 3, 4, for measuring the tension, which branch off from the various baths or resistance boards. The other pole-screw of the voltmeter is directly connected with the main anode-wire. From the main object-wire, a wire, whose cross-section depends on the strength of the working current, passes to the screw marked "strong" of the resistance board R_1; the screw marked "weak" of the resistance board R_1 is connected by a correspondingly stout wire with the object-wire of bath I, and at the same time with the binding-screw 1 of the shunt. The resistance board R_2, of the bath II, is in the same manner connected with the main object-wire, the bath, and the binding-screw 2 of the shunt; also the resistance boards R_3 and R_4 of the baths III and IV, which are not shown in the illustration. With the main anode-wire each bath is directly connected by leading the current to an anode-rod of the bath by means of binding-screws and a stout copper wire, and establishing a metallic connection between this anode-rod and the next one. However, instead of connecting both, the current may also be led from the main anode-wire to each anode-rod.

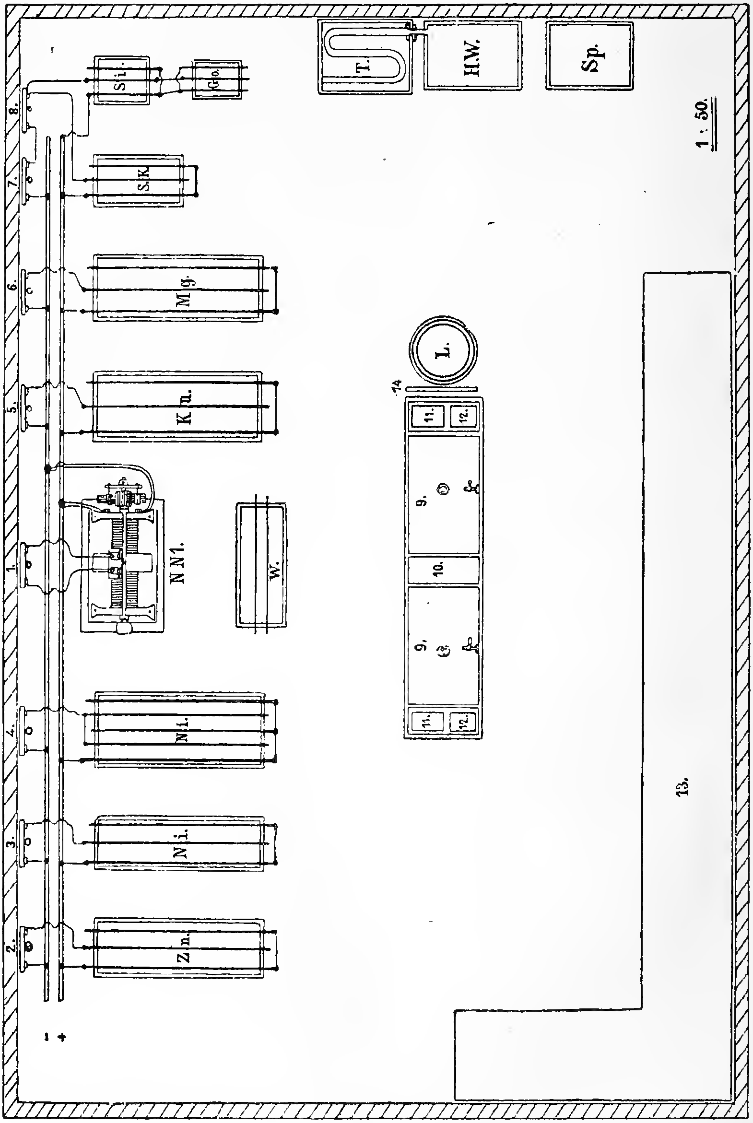
In the illustration, the handle of the shunt rests upon the second contact-button to the left, which is connected with the binding-screw 2 of the board. In the latter is secured the wire for measuring the tension of the resistance board R_2; and hence the voltmeter *V* will indicate the tension of the current in bath II. Suppose bath II is full of objects, and with the position of the handle of the resistance board at "weak," as shown in the illustration, the voltmeter indicates 1.5 volts, while the most suitable tension for the bath is 2.5 volts, the handle of the resistance board is turned to the left until the needle of the voltmeter indicates the desired 2.5 volts.

By turning the handle of the shunt *U* to the left, so that it rests upon the contact-button 1, the measuring wire of bath II is thrown out, and the voltmeter indicates the tension in bath I. If the handle rests upon contact-button 3, the tension in bath III is indicated, and so on.

In working the different baths in a larger establishment, each

bath is best directly fed from the main conducting wire after the current has been brought to the proper strength by the resistance board. Coupling the baths one after another so that the current

Fig. 61.



passes from one bath to the other is only practicable for metallurgical processes—gaining of metals—where every bath contains the same area of objects and anodes, has the same resistance, and works under the same conditions.

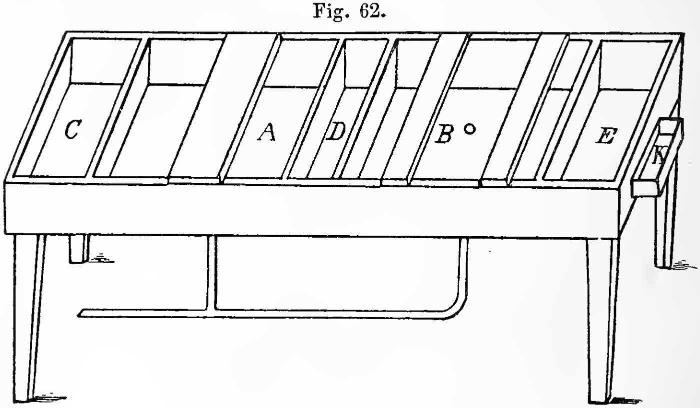
Fig. 61 shows the ground plan of an electro-plating establishment. NN^1 is a dynamo-electric machine, with 300 ampères at 4 volts' tension. The resistance board belonging to the machine, which is placed in the conductor, is indicated by No. 1, and is screwed to the wall. The main conductors, marked — and +, run along the wall, from which they are separated by wood, and consist of rods of pure copper 0.59 inch in diameter. The rods are connected with each other by brass coupling-boxes with screws. From the negative pole and the positive pole of the machine to the object-wire and anode-wire lead two wires, each 0.27 inch in diameter; one end of each is bent to a flat loop and secured under the pole screws of the machine, while the other ends are screwed into the second bore of the binding-screws screwed upon each conductor. To the right and left of the machine the baths are placed; *Zn*, indicating zinc bath; *Ni Ni*, nickel baths; *Ku*, copper cyanide bath; *Mg*, brass bath; *S K*, acid copper bath; *Si*, silver bath; and *Go*, gold bath. Each of the first-named five baths has its own resistance board designated by 2, 3, 4, 5, 6. However, before reaching the acid copper bath, and the silver and gold baths, the current is conducted through two resistance boards, 7 and 8. Since these baths require a current of only slight electro-motive force, it is necessary to place two, and in many cases even three or four, resistance boards, one after another, unless it be preferred to feed these baths with a special machine of less tension.

From Fig. 61 it will be seen that the current weakened by the resistance boards 7 and 8 serves for conjointly feeding the acid-copper, silver, and gold baths. Hence, practically, only one bath can be allowed to work at one time, as otherwise each bath would have to be provided with as many resistance boards as would be required for the reduction of the tension. For want of space the gold bath is placed in the sketch behind the silver bath; but as their resistance is not the same, they must also be placed parallel.

The coupling of the voltmeter and shunt is omitted in the illustration. Their arrangement will be understood from Fig. 59.

L is the lye-kettle; it serves for cleansing the objects by means of hot caustic potash or soda-lye from grinding and polishing dirt and oil. Instead of the preparatory cleansing with hot lye, which saponifies the oils, the objects may be brushed off with benzine, oil of turpentine, or petroleum, the principal thing being the removal of the greater portion of the grease and dirt, so that the final cleansing, which is effected with lime paste, may not require too much time and labor. It is also advisable to cleanse the objects, in one way or the other, immediately after grinding, as the dirt, which forms a sort of solid crust with the oil, is difficult to soften and to remove when once hard. The table for freeing the articles from grease stands alongside the lye-kettle, and is shown in perspective in Fig. 62. It consists of a box with legs, which is divided by four partitions into two large divisions, *A* and *B*, and three smaller ones, *C*, *D*, and *E*. The separate divisions are lined

Fig. 62.



with sheet lead. Across divisions *A* and *B* boards covered with cloth are laid, upon which the articles are brushed for the final cleansing with lime paste. Over each of these divisions is a rose-jet, provided with a cock, under which the articles are rinsed with water. The discharge pipes from *A* and *B* are provided with valves, and are tightly soldered into the bottom of the box. Of the smaller partitions, *D* serves for the reception of the lime

paste, while *C* and *E* each contain two pots or small stoneware vats with pickling fluid. In Fig. 61 these vats are indicated by 11 and 12. The two marked 11 contain dilute sulphuric acid for pickling iron and steel articles, while those marked 12 contain dilute potassium cyanide solution for pickling copper and its alloys, and Britannia, etc. For cleansing smaller articles, four men can at one time work on such a table; but for cleansing larger articles only two. The advantages of such a box-table are that everything is handy together; that the pickle, in case a pot should break, cannot run over the floor of the workshop; and that the latter is not spoiled by pickle dropping from the objects. The small box *K*, on the side of the table, serves for the reception of the various scratch-brushes.

Between the lye-kettle *L* and the box-table in Fig. 61 is a frame, 14, for the reception of brass and copper wire hooks of various sizes and shapes suitable for suspending the objects in the bath.

The reservoir *W*, filled with water, standing in front of the machine, serves for the reception of the cleansed and pickled objects, if for some reason or another they cannot be immediately brought into the bath.

H W is the hot water reservoir in which the plated objects are heated to the temperature of the hot water, so that they may quickly dry in the subsequent rubbing in the sawdust box *Sp*. Before polishing the deposits, iron and steel objects are thoroughly dried in the drying chamber *T* (Fig. 61), heated either by steam or direct fire. By finally adding to the appliances a large table, 13, for sorting and tying the objects on the copper wires, and a few shelves not shown in the illustration, everything necessary for operating without disturbance will have been provided.

What has been said in the preceding section in regard to the conducting wires, vats, conducting rods, anodes, etc., also applies to establishments using electro-dynamo machines.

In calculating the thickness of the conducting wires for dynamos, 1 square millimetre (0.001 square inch) of conducting cross-section is to be allowed for every 3 ampères for so-called short circuits up to 20 metres (21.87 yards). This is valid for currents up to 500 ampères; for longer circuits $1\frac{1}{2}$ to 2 ampères are calculated for the square millimetre of conducting cross-section.

CHAPTER V.

TREATMENT OF METALLIC ARTICLES.

THE objects having to undergo both a *mechanical* and *chemical* preparation, each of them will be considered separately.

A. *Mechanical Treatment.*

1. *Before electro-plating.*—If the objects are not to be electro-plated while in a crude state, which is but rarely feasible, the mechanical treatment consists in imparting to them a *cleaner surface by scratch-brushing*, or a *smoother* and *more lustrous* one by *grinding* and *polishing.* It may here be explicitly stated that scratch-brushing of electro-plated objects is not to be considered a part of their preparation, since such scratch-brushing is executed in the midst of or after the electro-plating process, its object being to effect a change of the electro-deposition in more than one direction, and not the cleansing of the surface of the metallic base. The following directions, therefore, apply only to the scratch-brushing of objects not electro-plated. The scratch-brushing of electro-depositions will be considered later on. In regard to grinding, we have to deal with the subject only in so far as it relates to smoothing rough surfaces by the use of grinding powders possessing greater hardness than the metal to be ground; with grinding in the sense of instrument-grinding, the primary object of which is to provide the instrument with a cutting edge, we have nothing to do.

Scratch-brushing may be effected either by hand or by a scratch-brush lathe. In the first place scratch-brushes of more or less hard brass or steel wire, according to the hardness of the metal to be manipulated, are used. Various forms of brushes are employed, the most common ones being shown in the accompanying illustrations (Figs. 63 to 71).

Fig. 70 shows swing brushes for frosting or satin finish, with four knots of medium brass or steel wire, and Fig. 71 the plater's lathe goblet scratch-brush.

In scratch-brushing it is recommended to remove, or at least to soften, the uppermost hard and dirty crust (the scale) by immersing the objects in a pickle, the nature of which depends on the

Fig. 63.

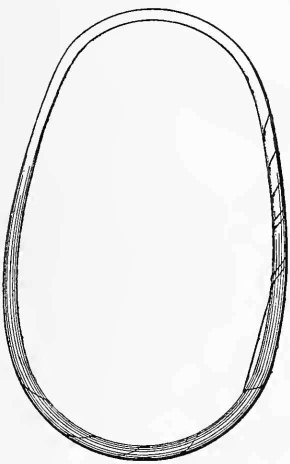


Fig. 64.

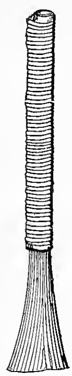


Fig. 65.

Fig. 66.

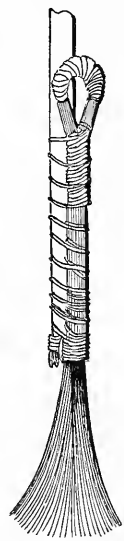


Fig. 67.

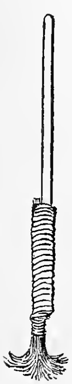


Fig. 68.

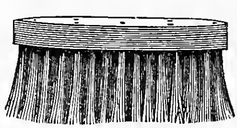


Fig. 69.

variety of metal, so that a complete removal of all impurities and non-metallic substances may be effected by means of the scratch-brush in conjunction with sand, pumice-stone, powder, or emery. The work is complete only when the article shows a clean metallic surface, otherwise the brushing (scouring) must be con-

tinued. Scratch-brushes must be carefully handled and looked after, and their wires kept in good order. When they become bent they have to be straightened, which is most readily effected by several times drawing the brush, held in a slanting position, over a sharp grater such as is used in the kitchen. By this means the wires become disentangled and straightened out.

Fig. 70.

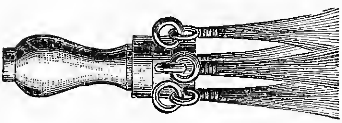
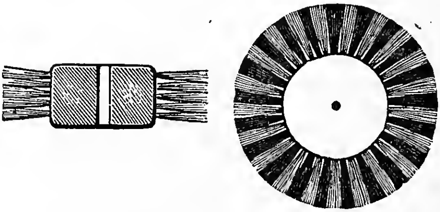


Fig. 71.

Hand scratch-brushing being slow and tedious work, large establishments use circular scratch-brushes which are attached to the spindle of a lathe. These circular brushes consist of round wooden cases in which, according to requirement, 1 to 6 or more rows of wire bundles (see Fig. 72) are inserted.

Fig. 72.



Brushes with wooden cases are, however, more suitable for scratch-brushing deposits than for cleansing the metallic base, since for the latter purpose a more energetic pressure is usually applied, in consequence of which the bundles bend and even break off, if the wire is anywise brittle. For cleansing purposes a circular scratch-brush, which the workman can readily refurnish

with new bundles of wire, deserves the preference. It is constructed as follows: A round iron disk about 0.11 inch thick, and from $5\frac{3}{4}$ to $7\frac{3}{4}$ inches in diameter, is provided in the centre with a hole so that it can be conveniently placed upon the spindle of the lathe. At a distance of from 0.19 to 0.31 inch from the periphery of the disk holes 0.079 to 0.11 inch in diameter are drilled, so that between each two holes is a distance of 0.15 inch. Draw through these holes bundles of wire about 3.93 inches long, so that they project an equal distance on both sides. Then bend the bundles towards the periphery, and on each side of the iron disk place a wooden disk 0.31 to 0.39 inch thick. The periphery of the wooden disk, on the side next to the iron disk, should be turned semi-annular, so that the wooden disks when secured to the spindle press very lightly upon the wire bundles, and the latter remain very mobile. When a circular scratch-brush constructed in this manner and secured to the lathe is allowed to make from 1800 to 2000 revolutions per minute, the bundles of wire, in consequence of the centrifugal force, stand very rigid, but being mobile will give way under too strong a pressure without breaking off, and can thus be utilized to the utmost. When required, the iron disk can be refurnished with wires in less than half an hour. An error frequently committed is that the objects to be cleansed are pressed with too heavy a pressure against the wire brushes. This is useless, since only the sharp points of the wire are effective, the lateral surfaces of the bundles removing next to nothing from the articles.

Brushes.—A definition of these instruments is unnecessary, and we shall simply indicate the various kinds suitable to the different operations.

The fire-gilder employs, for equallizing the coating of amalgam, a long-handled brush, the bristles of which are long and very stiff. The electro-gilder uses a brush (Fig. 73) with long and flexible bristles.

For scouring with sand and pumice-stone alloys containing nickel, such as German silver, which are difficult to cleanse in acids, the preceding brush, with smaller and stiffer bristles, used.

The gilder of watch-works has an oval brush (Fig. 74), with stiff and short bristles for graining the silver.

The galvanoplastic operator, for coating moulds with black-lead, besides a number of pencils, uses also three kinds of brushes —the watchmaker's (Fig. 75), a hat-brush, and a blacking-brush. The bronzer uses all kinds of brushes.

Fig. 73.

Fig. 74.

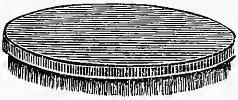


Fig. 75.

Brushes are perfectly freed from adherent grease by washing with benzine or bisulphide of carbon.

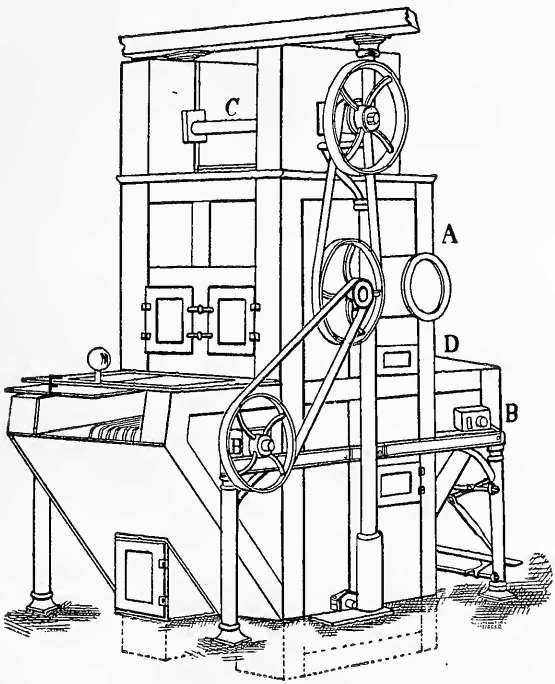
In large establishments engaged in electro-plating cast-iron without previous grinding, the use of the sand-blast in place of the circular wire brush has recently been introduced with great advantage. Objects with deep depressions, which cannot be reached with the scratch-brush, as well as small objects, which cannot be conveniently held in the hand and pressed against the revolving scratch-brush, can be brought by the sand-blast into a state of sufficient metallic purity for the electro-plating process. However, while the revolving scratch-brushes impart to the objects a certain lustre, they acquire by the sand-blast a dead lustre, and, hence, the blast is also frequently used for the purpose of deadening lustrous surfaces to their entire extent, or of producing contrasts—for instance, dead designs upon a lustrous ground, or *vice versa*.

Fig. 76 shows such a sand-blast. The compressed air, whose pressure must be at least equal to an $18\frac{1}{2}$-inch column of water, passes through the blast-pipe *A* into a nozzle running horizontally through the machine, and carries away from there a jet of sand, which falls into the outflowing blast and is hurled upon the objects placed under the nozzle. The objects rest upon sheet-iron plates or in boxes of sheet-iron, which, moving at a slow rate, pass under the nozzle; the motion is effected by the shafts *B B*, with the use of belts. To prevent dust, the machine is encased in a wooden or sheet-iron case, a few windows allowing

a view of the interior. The sand used in blasting collects in a box, and is returned to the sand-reservoir by an elevator.

The jet of sand acts not only upon the upper side of the objects, which it strikes first, but also almost as energetically upon the lower, so that, as a rule, the cleansing process is com-

Fig. 76.



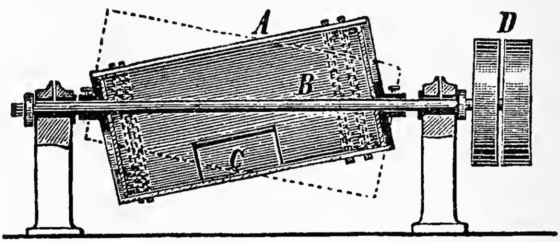
pleted by one operation. Objects of a specially unfavorable shape must be passed twice or three times under the nozzle.

If a clean metallic surface is to be given at one time to a large number of small articles, such as buckles, steel beads, metal buttons, steel watch-chains, ferrules, etc., a *tumbling drum* or *box* is frequently used. It generally consists of a cylindrical or polygonal box having a side door for the introduction of the work, together with sharp sand or emery, and is mounted hori-

zontally on an axis furnished with a winch or pulley, so as to be revolved either by hand or power, as may be desired. In order to prevent certain objects, like hooks for ladies' dresses and the like, from catching each other and accumulating into a mass, a number of nails or wooden pegs are fixed in the interior of the drum.

A very practical form of tumbling drum, in which a change of position of the contents must constantly take place, is shown in Fig. 77. The drum *A*, of wood or iron, is obliquely placed upon the shaft *B*. The objects are introduced through the door *C*. The drum is revolved by a crank, or by a belt by means of the

Fig. 77.



pulley *D*. All portions of the drum describe thereby ellipses, the walls of the drum being now raised (indicated by the dotted lines) and then lowered, so that the objects in the drum are in constant motion and rub against each other. By introducing together with the objects a suitable polishing powder with oil or water, such drums may be used not only for the preparatory cleansing of the objects, but also for polishing.

For ordinary polishing the articles are brought into the tumbling drum, together with small pieces of leather waste (leather shavings), and taken out in one or two days. However, to produce an actually good polish a somewhat more complicated method has to be pursued. The articles are first freed from adhering oxide by washing in water containing 5 per cent. of sulphuric acid, rinsed, and dried in a drying chamber or in a pan over a fire. They are next brought into the tumbling drum together with sharp sand, such as is used in glass-making, and revolved for

about 12 hours, when they are taken from the drum and freed from the admixed sand by sifting. They are then returned to the drum, together with soft, fibrous sawdust, to free them from adhering sand, and at the same time to give them a smoother surface. They are now again taken from the drum, freed from sawdust and returned to the drum, together with leather shavings. They now remain in the drum until they have acquired the desired polish, which, according to the size and shape of the articles and the degree of polish required, may frequently take two weeks or more. Articles of different shapes and sizes are best treated together, time being thereby saved. The process is also accelerated by adding some fat oil to the leather shavings, which, of course, must be omitted when, after long use, the shavings have become quite greasy. The drum should be filled about half full, otherwise the articles do not roll freely and polishing is retarded. On the other hand, when the drum is less than half full there is danger of the articles bending, or in case they are hardened, for instance buckles, of breaking.

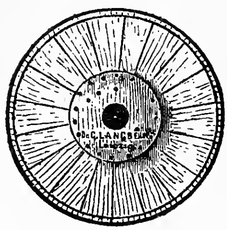
For many purposes polishing in the tumbling drum is of great advantage, since, independent of its cheapness, the sharp edges of the articles are at the same time rounded off. However, with articles the edges of which have to remain sharp, the process cannot be employed.

The tumbling drum in which the articles are treated with sand cannot be used for polishing with leather shavings, it being next to impossible to free it entirely from sand. The drums should make from 50 to 70 revolutions per minute; if allowed to revolve more rapidly, the articles take part in the revolutions without rolling together, which, of course, would prevent polishing.

The brightening of articles of iron and steel may be simplified by using water to which 1 per cent. of sulphuric acid has been added. The drum used for the purpose must, of course, be water-tight. By the addition of sand the process is accelerated. Nickel and copper blanks for coins are also cleansed in this manner. They are brought into the tumbling drum, together with a pickling fluid and, when sufficiently treated, are taken out, rinsed, dried in sawdust, and finally stamped.

Grinding.—For grinding the objects for the electro-plating process, wooden disks covered with leather coated with emery of various degrees of fineness are almost exclusively used. The wooden disks are made of thoroughly seasoned poplar in the manner shown in Fig. 78. The separate pieces are radially glued together, and upon each side in the centre a strengthening piece is glued and secured with screws so that each segment of the wooden disk is connected with the strengthening piece. The centre of the disk is then provided with a hole corresponding to the diameter of the spindle of the grinding lathe, to which it is secured by means of wedges. The periphery as well as the sides are then turned smooth. A good quality of leather previously soaked in water and cut into strips corresponding to the width of the wooden disk is then glued to the periphery of the disk, and still further secured by pins of soft wood. When the glue is dry the disk is again wedged upon the spindle and the leather carefully turned; it is then ready for coating with emery.

Fig. 78.



For this purpose three different kinds of emery are used, a coarse quality (Nos. 60 to 80) for preparatory grinding, a finer quality (No. 00) for fine grinding, and the finest quality (No. 0000) for imparting lustre. The disks thus coated are termed respectively "roughing wheel," "medium wheel," and "fine wheel." With the first the surfaces of the objects are freed from the rough crust. The coarse-grained emery used for this purpose, however, leaves scratches, which have to be removed by grinding upon the medium wheel until the surface of the objects shows only the marks due to the finer quality of emery, which are in their turn removed by the fine wheel.

In most cases brushing with a circular bristle brush may be substituted for the last grinding, the articles being moistened with a mixture of oil and emery No. 0000. Care must be had not to execute the brushing, nor the grinding with the finer quality of emery, in the same direction as the preceding grinding, but in a direction at a right angle to it.

Treatment of the grinding disks.—The coating of the roughing wheels with emery is effected by applying to them a good quality of glue and rolling them in the dry coarse emery powder. For the medium and fine wheels, however, the emery is mixed with the glue and the mixture applied to the leather. When the first coat is dry, a second is applied, and finally a third. The whole is then thoroughly dried in a warm place. Before use, a piece of tallow is held to the revolving disk for the purpose of imparting a certain greasiness to it, and in order to remove any roughness due to an unequal application of the emery it is smoothed by pressing a smooth stone against it. While the preparatory grinding upon the roughing wheel is executed dry, *i. e.*, without the use of oil or fat, in fine grinding the objects are frequently moistened with a mixture of oil or tallow and the corresponding No. of emery. When the layer of emery is used up, the remainder is soaked with warm water and scraped off with a dull knife. The leather of the disks on which oil or tallow has been used is then thoroughly rubbed with caustic lime or Vienna lime* to remove the greasiness, which would prevent the adherence of the layer of glue and emery to be applied later on. When the leather is thoroughly dry a fresh layer of emery may at once be applied.

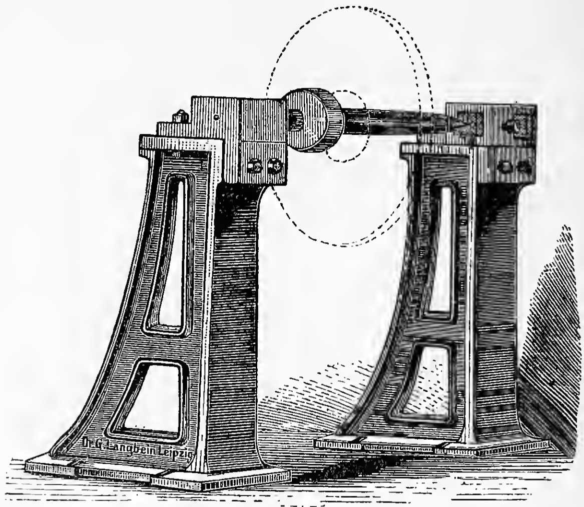
Grinding lathes.—For use, the grinding disks or buffs are wedged upon a conical cast-steel spindle provided with a pulley and working in hard-wood bearings, as plainly shown in Fig. 79. The cast-iron standards are screwed to the floor; the wooden bearings can be shifted forward and backward by wedges and secured in a determined position by a set screw, thus facilitating the removal of the spindle after throwing off the belt. The disks being wedged upon a conical spindle they always run centrically. The changing of the disks requires but a few seconds, and on account of the slight friction of the points of the spindle in the wooden bearings the consumption of power is very slight.

To avoid the necessity of throwing off the belt while changing the grinding disks, double machines (Fig. 80) are used, the prin-

* Vienna lime is prepared from a variety of dolomite which is first burned, then slacked, and finally glowed for a few hours. It consists of lime and magnesia, and should be kept in well-closed cans, as otherwise it absorbs carbonic acid and moisture from the air, and becomes useless.

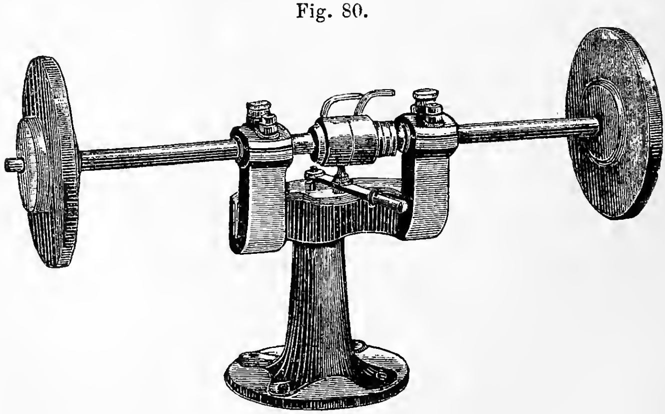
ciple of conical spindles being, however, preserved. The shaft is provided with loose and fast pulley and coupling lever.

Fig. 79.



Grinding is executed by pressing the surfaces to be ground against the face of the disk, moving the objects constantly to and

Fig. 80.

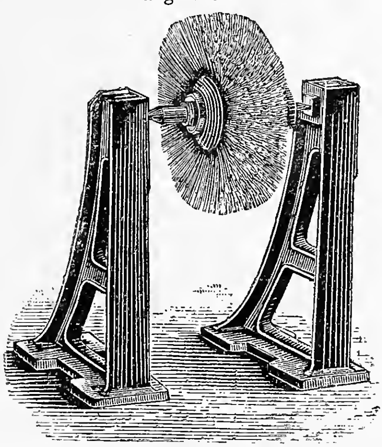


fro. The operation requires a certain manual skill, since, without good reason, no more should be ground away on one place than on another. Special care and skill are required for grinding large round surfaces.

If the objects are not to be treated with the fine wheel, fine grinding is succeeded by brushing with oil and emery by means of circular brushes formed of bristles set in disks of wood (see Fig. 85). Genuine bristles being at present very expensive, vegetable fibre, so-called *fibres*, has been successfully substituted for them, the wooden disk being replaced by an iron case, in the bell-shaped cheeks of which the fibre-bundles are secured by means of strong nuts. Before use it is advisable to saturate the fibre-bundles with oil in order to deprive them of their brittleness, and thus improve their lasting quality.

The grinding lathe (Fig. 81) is provided with such a fibre-brush; it can, of course, be just as well placed upon the conical

Fig. 81.



spindles of double machines. The iron case is provided with a conical hole corresponding exactly to the conical spindle, the large frictional surface preventing the turning of the brush upon the spindle or its running off.

In regard to grinding the various metals, the procedure, according to the hardness of the metal, is as follows:—

Iron and steel articles are first ground upon the roughing wheel, then fine-ground upon the medium wheel, and finally upon the fine wheel, or brushed with emery with the circular brush. Very rough iron surfaces may first be ground upon solid emery wheels before being worked upon the roughing wheel.

For depressed surfaces which cannot be reached with the large emery disks, small disks of walrus-hide coated with glue and emery are placed upon the point of the spindle of the polishing lathe (see Fig. 85).

Brass and copper castings are first ground upon roughing wheels, which have lost part of their sharpness and will no longer attack iron; they are then ground fine upon the medium wheel, and finally polished upon cloth or felt disks (bobs). (See below, under Polishing.)

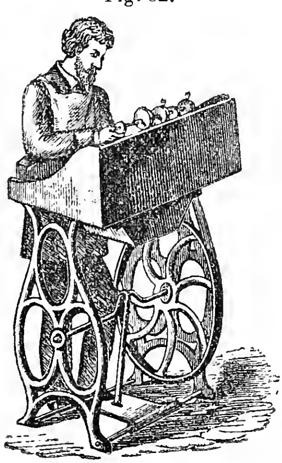
Sheets of brass, German silver, and copper, as furnished by rolling-mills, are only brushed with emery and then polished with Vienna lime or rouge upon bobs.

Zinc castings, as, for instance, those produced in lamp factories, are first thoroughly brushed by means of circular brushes and emery, and then polished upon cloth bobs.

Sheet zinc is only polished with Vienna lime and oil upon cloth bobs secured to the spindle shown in Fig. 86.

Polishing.—As will be seen from the foregoing, polishing serves for making the articles ready, *i. e.*, the final lustre is imparted to them upon soft polishing disks with the use of fine polishing powders. The polishing disks or bobs of fine felt, shirting, or cloth, are secured to the polishing lathe, and, according to the hardness of the metal to be polished, make 2000 to 2500 revolutions per minute. A foot-lathe, such as is shown in Fig. 82, makes generally not over 1800 revolutions per minute. Cloth bobs are made by placing pieces of cloth one upon another in the manner described under "Nickelling of sheet zinc," cutting out the centre corresponding to the diameter of the spindle, and securing the disks of cloth by means of nuts betwen two wooden cheeks upon the spindle of the polishing lathe. In place of cloth bobs, solid round disks of felt or wooden disks covered with a layer of felt may be used, especially for polishing smooth objects without

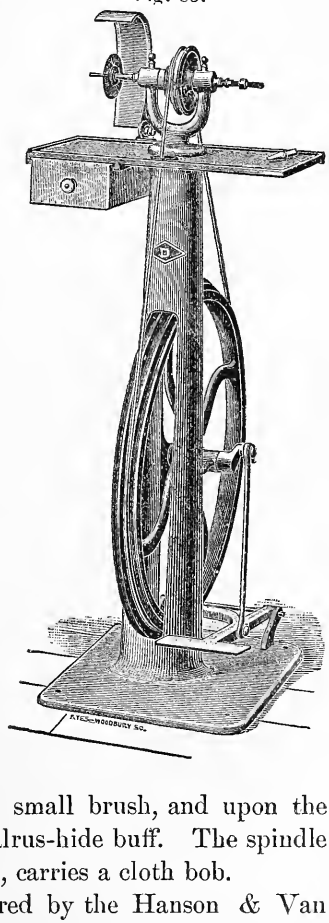
Fig. 82.



depressions, the fineness and softness of the felt depending on the degree of polish to be imparted and the hardness of the metal to be manipulated.

The foot-lathe shown in Fig. 83 is designed for light grinding, polishing, and buffing, and is especially suited for polishing silver-plate and silver. It is constructed of iron and steel, and made very rigid and strong to prevent vibration. It stands 3 feet 9 inches from floor to centre of spindle, has a 26-inch driving-wheel turned with grooves for three different speeds, and will run the spindle easily at from 300 to 3000 revolutions per minute. The spindle as shown in the illustration is suitable for leather, muslin, and swan's-down bobs, buffs, and mops. This can be unscrewed and replaced by another spindle, which is furnished with a taper screw for the bosses of circular brushes.

Fig. 83.



Double polishing lathes, according to the American patterns (Figs. 84 and 85), are used for polishing objects of not too large dimensions, while the lathe shown in Fig. 86 serves chiefly for polishing large sheets, the latter being placed upon a smooth wooden support which rests upon the knees of the workman, as will be described later on in speaking of the nickelling of sheet zinc.

Fig. 85 shows a double polishing lathe of larger size; it carries on one side a large felt disk and a small brush, and upon the other a circular brush and a small walrus-hide buff. The spindle of the small polishing lathe, Fig. 84, carries a cloth bob.

The lathe (Fig. 87) is manufactured by the Hanson & Van Winkle Co., of Newark, N. J. It is shown on a cast-iron pedestal,

from which it can be disconnected and placed on a bench, if required. It is made to run at a speed of 3000 revolutions per

Fig. 84.

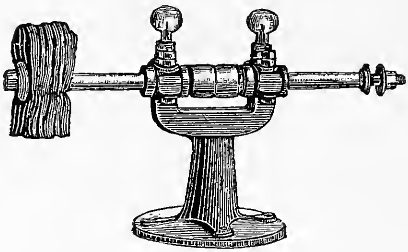


Fig. 85.

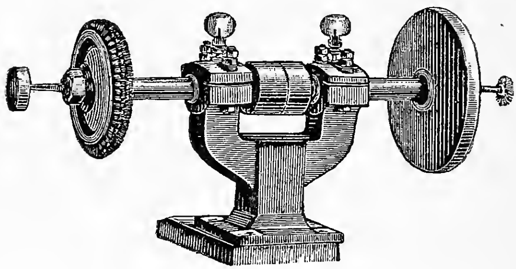
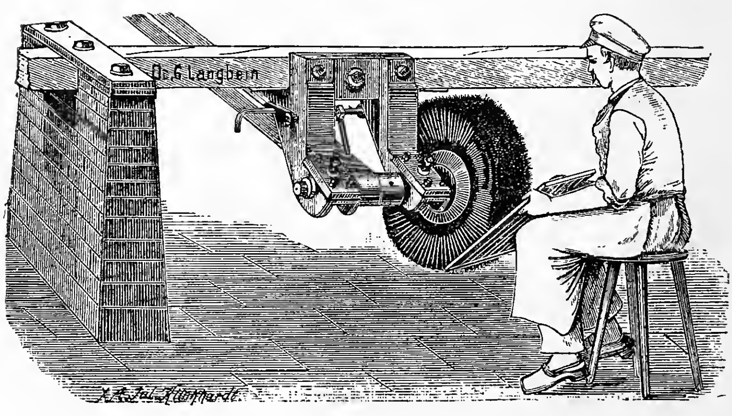


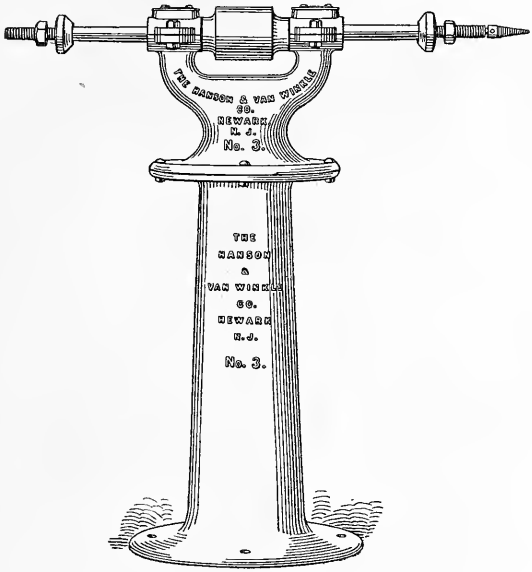
Fig. 86.



minute, at which speed the most satisfactory results are obtained with muslin buffs, etc.

The lathe is made with steel spindles, hard-metal bearings, and is designed for quick speeds. By reason of the distribution of

Fig. 87.



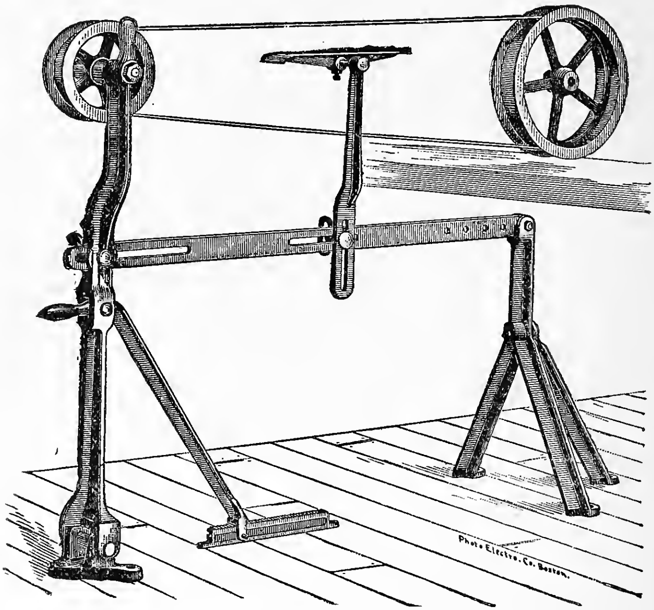
metal it runs without vibrations. It stands 10 inches high to centre, has spindle 3 feet long, $1\frac{1}{4}$ inches diameter, with collars on both ends of spindle. The pulley is 4 inches in diameter, $3\frac{1}{2}$ inches face. The spindle is 1 inch diameter between collars. The lathe is furnished with fast and loose pulleys where required. Detachable taper ends are shown, on which the smallest brush can be run.

The *belt strapping attachment* shown in Fig. 88, which is also manufactured by the Hanson & Van Winkle Co., of Newark, N. J., can be applied to the above-described or other size polishing lathe that will carry a 12-inch wheel. Flanged wheels are supplied to readily take the place of the polishing wheel, and a canvas and rubber endless belt from 1 to $2\frac{1}{2}$ inches wide and 12 feet total length is used, to which the different grades of emery or other material are applied.

These machines, of which several styles are made, are largely

used by manufacturers of saddlery and carriage hardware, and on regularly shaped articles that cannot be conveniently polished on a circular wheel.

Fig. 88.



Self-acting polishing lathes for sheet-metal will be discussed under "Nickelling of zinc sheet."

According to the hardness of the material to be polished, ferric oxide (colcothar or rouge), tripoli, Vienna lime, etc., in the state of an impalpable powder, and generally mixed with oil, or sometimes with alcohol, are used as polishing agents. For hard metals an impalpable rouge of great hardness (No. F of commerce) is employed, for softer metals a softer rouge (No. F F F) or Vienna lime, tripoli, etc.

It is of advantage to melt the rouge with melted wax and a small quantity of tallow, and cast the mixture in moulds with the aid of strong pressure. The sticks thus formed are sufficiently greasy to render the use of oil superfluous. In order to impregnate the surface of the polishing bob with the polishing material,

hold one of the sticks for a second against the revolving disk, and then polish the objects by pressing them against the disk, diligently moving them to and fro. The polishing bob must not be too heavily impregnated with rouge, since a surplus of the latter smears instead of cutting well. In polishing with Vienna lime, it, is advisable to moisten the objects to be polished, with oil, while the polishing bobs are saturated with the lime by holding a piece of it against them.

Another process of polishing, called *burnishing*, is executed by means of tools usually made of steel for the first or *grounding* process, or of a very hard stone, such as agate or blood-stone, for finishing. Burnishing is applied to the final polishing of depositions of the noble metals.

2. *Mechanical treatment during and after the electro-plating process.*—In this connection, *scratch-brushing* the depositions will be first considered, the object of this operation being, on the one hand, to promote the regular formation of certain deposits; on the other, to effect a change in the physical properties of the deposits; and, finally, to ascertain whether the deposit adheres to the basis-metal.

If it is seen by the irregular formation of the deposit that the basis-metal has not been cleaned with sufficient care by the preparatory scratch-brushing, the object has to be taken from the bath and the defective places again scratch-brushed with the application of water and sand, or pumice-stone, when the object is again pickled and replaced in the bath.

On the other hand, electro-deposited metals are always more or less porous, they having, so to say, a net-like structure, though it may not be visible to the naked eye. By scratch-brushing the meshes of the net are made closer by particles of metals being forced into them by the brush, and the deposit is thus rendered capable of receiving additional layers of metal. Furthermore, by scratch-brushing the dead deposits acquire a certain lustre which is enhanced by the subsequent polishing process. Finally, by an unsparing application of the scratch-brush, it will best be seen whether the union of the deposit with the basis-metal is sufficiently intimate to stand the subsequent mechanical treatment in polishing without becoming detached.

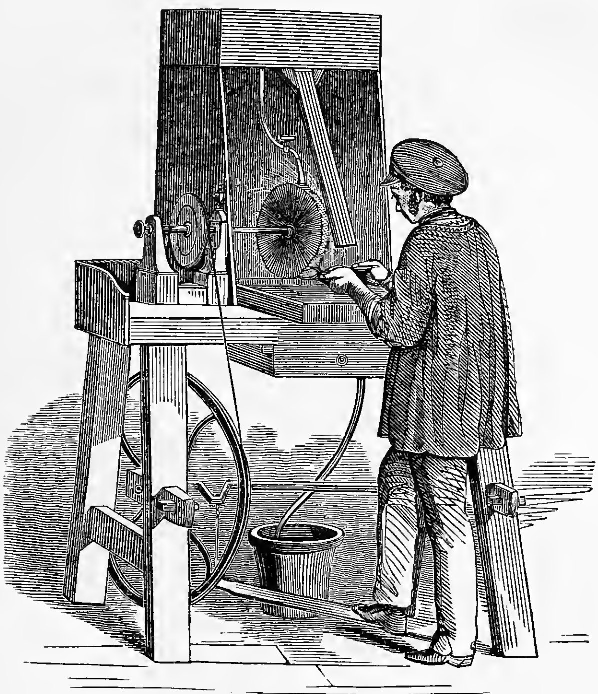
According to the object in view, and the hardness of the deposit to be manipulated, scratch-brushes of steel or brass wire are chosen. For *nickel*, which, as a rule, requires scratch-brushing least, and chiefly only for the production of very thick deposits, steel wire of 0.2 millimetre thickness is taken; for deposits of *copper, brass, and zinc*, brass wire of 0.2 millimetre; for *silver*, brass wire of 0.15 millimetre; and for *gold*, brass wire of 0.07 to 0.1 millimetre. Scratch-brushing is seldom done dry; the tool as well as the pieces should be constantly kept wet with liquids, especially such as produce a lather in brushing, for instance, water and vinegar, or sour wine, or solutions of cream of tartar or alum, when it is desired to brighten a gold deposit which is too dark; but that most generally used is a decoction of licorice-root, of horse-chestnut, of marshmallow, of soapwort, or of the bark of Panama-wood, all of which, being slightly mucilaginous, allow of a gentle scouring with the scratch-brush, with the production of an abundant lather. A good adjunct for scratch-brushing is a shallow wooden tub containing the liquid employed, with a board laid across it nearly level with the edges, which, however, project a little above. This board serves as a rest for the pieces.

The hand scratch-brush, when operating upon small objects, is held by the workman in the same manner as a paint brush, and is moved over the object with a back and forward motion imparted by the wrist only, the forearm resting on the edge of the tub. For larger objects, the workman holds his extended fingers close to the lower part of the scratch-brush, so as to give the wires a certain support, and, with raised elbow, strikes the pieces repeatedly, at the same time giving the tool a sliding motion. When a hollow is met with, which cannot be scoured longitudinally, a twisting motion is imparted to the tool.

The lathe brush (Fig. 89) is mounted upon a spindle, and is provided above with a small reservoir to contain the lubricating fluid, a small pipe with a tap serving to conduct the solution from this to a point immediately above the revolving brush. The top of the brush revolves towards the operator, who presents the object to be scratch-brushed to the bottom. The brush is surrounded by a wooden cage or screen to prevent splashing. To

protect the operator against the water projected by the rapid motion, there is fixed to the top of the frame a small inclined board, which reaches a little lower than the axis of the brush without touching it. This board receives the projected liquid,

Fig. 89.



and lets it fall into a zinc trough, which forms the bottom of the box. Through an outlet provided in one of the angles of the trough a gum tube conveys the waste liquid to a reservoir below. After scratch-brushing every trace of the lubricating liquid must be washed away before placing or replacing the objects in the bath.

The finished electro-plated objects are first rinsed in clean water to remove the solution constituting the bath adhering to them; they are next immersed in hot water, where they remain until they have acquired the temperature of the water, and are then quickly

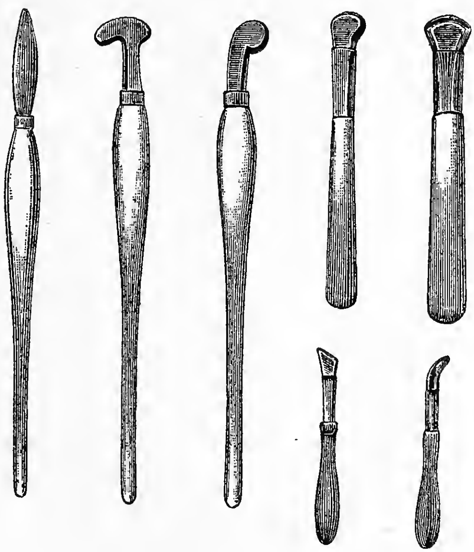
rubbed with dry, hot sawdust. It is best to use sawdust of soft wood, free from tannin, such as maple, poplar, or pine; oak sawdust is not suitable for the purpose on account of its content of tannin, which imparts a dirty coloration to the electro-deposits. Boxwood sawdust, though much used, is not sufficiently absorbent, and sticks to the moist objects. The sawdust used must be freed from coarser particles of wood by sifting. For holding the sawdust a zinc box with double bottom is frequently used, which is heated by waste steam or some other process. In order to remove all moisture from the pores it is advisable to place plated objects of iron and steel for a few hours in an oven heated to between 140° and 175° F. A very good method of freeing nickelled objects from all moisture which may have collected in the pores is to immerse them for about ten minutes in *boiling* linseed oil, and, after allowing them to drain off, to remove the adhering oil by rubbing with sawdust. According to some electro-platers, the deposit of nickel thus treated loses its brittleness and will stand bending several times, for instance, wire, sheets, etc., without breaking. Experiments made by Dr. George Langbein did not confirm these statements, but the security against rust of the nickelled iron objects was found to be considerably enhanced by boiling in linseed oil.

The electro-plated objects, when dry, are finely polished, which is effected upon polishing bobs of fine felt, cloth, or flannel, with the use of fine rouge, Vienna lime, tripoli, etc., or by burnishing.

Nickel deposits are almost without exception polished upon cloth or felt bobs with rouge or Vienna lime and oil. *Copper and brass deposits* are polished with fine flannel bobs, the polishing powder being applied very sparingly. *Deposits of tin* are generally only scratch-brushed, it being impossible to impart great lustre to this metal by polishing with bobs; after drying, the deposit is polished with whiting. *Deposits of gold and silver* as well as of *platinum* are polished by burnishing, the steel burnisher being used for the *grounding* process, and an agate or bloodstone burnisher for finishing. The operation of burnishing is carried on as follows: Keep the tool continually moistened with soapsuds. Take hold of the tool very near to the end, and lean very hard with it on those parts which are to be burnished, causing it

to glide by a backward and forward motion without taking it off the piece. When it is requisite that the hand should pass over a large surface at once without losing its point of support on the work bench, be careful in taking hold of the burnisher to place it just underneath the little finger. By these means the work is done more quickly, and the tool is more solidly fixed in the hand.

Fig. 90.



The burnishers are of various shapes to suit the requirements of different kinds of work, the first rough burnishing being often done by instruments with comparatively sharp edges, while the finishing operations are accomplished with rounded ones. Fig. 90 illustrates the most common forms of burnishers of steel and agate. Both must be free from cracks and highly polished. To keep them free from blemishes they are from time to time polished by vigorously rubbing them with fine tin putty, rouge or calcined alum upon a strip of leather fastened upon a piece of wood which is placed in a convenient position upon the work bench.

The objects polished with Vienna lime and oil, or with rouge, have to be freed from adhering polishing dirt, which, with flat

smooth objects, is effected by wiping with a flannel rag and Vienna lime, and in those with depressions or dead surfaces by brushing with a soft brush and soap-water, and then drying in sawdust.

B. *Chemical Treatment.*

While the preparation of a pure metallic and, at the same time, smoother surface is the aim of the mechanical treatment, the chemical preparation of the objects serves, on the one hand, the purpose of facilitating the mechanical treatment by softening and dissolving the impure surface, and, on the other, of freeing the mechanically prepared objects from adhering oil, grease, dirt, etc., so as to bring them into the state of *absolute purity* required for the electro-plating process.

Pickling.—The composition of the pickling fluid varies according to the nature of the metal which is to be pickled.

Cast-iron and wrought-iron objects are pickled in a mixture of 1 part by weight of sulphuric acid of 66° Bé. and 15 of water; hydrochloric acid may be substituted for the sulphuric acid.

An excellent pickle for iron is obtained by mixing 10 quarts of water with 28 ozs. of concentrated sulphuric acid,* dissolving 2 ozs. of zinc in the mixture and adding 12 ozs. of nitric acid. This mixture makes the iron objects bright, while they become black in dilute sulphuric or hydrochloric acid. To cleanse badly rusted iron objects without attacking the iron itself, it is recommended to pickle them in a concentrated solution of chloride of tin, which, however, should not contain too much free acid, as otherwise the iron is attacked.

The duration of pickling depends on the more or less thick layer of scale, etc., which is to be removed or softened; the process may be considerably assisted and the time shortened by frequent scouring with sand or pumice. The pickled articles are rinsed in cold water, then immersed in hot water, and dried in sawdust. In order to neutralize the acid remaining in the pores, it is advisable to make the rinsing water alkaline by the addition of caustic potash or soda, etc.

* The acid should be poured into the water, and not the water into the aci l.

Zinc objects are only pickled when they show a thick layer of oxide, in which case pickling is also effected in dilute sulphuric or hydrochloric acid, and brushing with fine pumice. A very useful pickle for zinc consists of sulphuric acid 100 parts by weight, nitric acid 100, and common salt 1. The zinc objects are immersed in the mixture for one second, and then quickly rinsed off in water which should be frequently changed.

Copper and its alloys, *brass, bronze, tombac,* and *German silver,* are cleaned and brightened by dipping in a mixture of nitric acid, sulphuric acid, and lampblack, a suitable pickle consisting of sulphuric acid, of 66° Bé., 50 parts by weight, nitric acid, of 36° Bé., 100, common salt 1, and lampblack 1. In order to remove the *brown* coating, due to cuprous oxide, the objects are first pickled in dilute sulphuric acid, and then dipped for a few seconds, with constant agitation, in the above-mentioned pickle until they show a bright appearance. They are then immediately rinsed in water to check any further action of the pickle.

If objects of copper or its alloys are not to be subjected, after pickling, to further mechanical treatment, or are to be at once placed in the electro-plating bath, it is best to execute the pickling process in two operations by treating them in a *preliminary pickle* and brightening them in the *bright-dipping bath.* The *preliminary pickle* consists of nitric acid, of 36° Bé., 200 parts by weight, common salt 1, lampblack 2. In this preliminary pickle the articles are allowed to remain until all impurities are removed, when they are rinsed in a large volume of water, dipped in boiling water so that they quickly dry, and plunged into the *bright-dipping bath,* which consists of nitric acid, of 40° Bé., 75 parts by weight, sulphuric acid, of 66° Bé., 100, and common salt 1. It is not advisable to bring the objects which have passed through the preliminary pickle and rinsing water directly, while still moist, into the bright-dipping bath, since for the production of a beautiful pure lustre the introduction of water into the bright-dipping bath must be absolutely avoided. Hence the objects treated in the preliminary pickle should first be dried by heating in hot water, shaking the latter off.

Potassium cyanide, dissolved in ten times its weight of water, is often used instead of the acid pickle for brass, especially when

it is essential that the original polish upon the objects should not be destroyed, as in the preparation of articles for nickel-plating. The objects should remain in this liquid longer than in the acid pickle, because the metallic oxides are far less soluble in this than in the latter. In all cases the final cleaning in water must be observed.

All acid pickles used for different kinds of work should be kept distinct from each other, so that one metal may not be dipped into a solution containing a more electro-negative metal, which would deposit upon it by a chemical exchange.

The pickled objects must not be unnecessarily exposed to the air, and should be transferred as quickly as possible from the pickle to the wash waters and then to the electro-plating bath, or, if this is not feasible, kept under pure water. Pickled objects which are not to be plated are carefully washed in water, which should be frequently changed, rinsed, drawn through a solution of tartar, and dried by dipping in hot water and rubbing with saw-dust.

Places soldered with soft solder, as well as parts of iron, become black by pickling, and have to be brightened by scouring with pumice, or by scratch-brushing

It is frequently required that bright objects of brass or other alloy of copper should be given a dead or dull surface by pickling, so that after plating they show a beautiful dead lustre. This may be effected in various ways. Every bright-dipping bath acts as a dead dip if the articles are allowed to remain in it for a longer time and at a higher temperature. A better effect is, however, produced by adding zinc sulphate (white vitriol) to the pickle, the deadening being the stronger the more zinc sulphate is added. A good dead dip is prepared by adding a solution of 0.35 oz. of zinc sulphate in $3\frac{1}{2}$ ozs. of water to the cold mixture of $6\frac{1}{2}$ lbs. of nitric acid, of 36° Bé., 4.4 lbs. of sulphuric acid, of 66° Bé., and $\frac{1}{2}$ oz. of common salt. According to the shade desired, the articles are left in this mixture for 2 to 10 minutes, and as they come from it with a faded earthy appearance, they are plunged momentarily into a bright-dipping bath, whereby they acquire a dead lustre, and are then quickly rinsed in a large volume of clean water.

Generally speaking, it may be said that less depends on the composition of the pickle than on quick and skillful manipulation; and as good results have always been obtained with the above-mentioned mixture, there is no reason for repeating the innumerable receipts given for pickles. The main points are to have the acid mixture as free from water as possible, further the development of hyponitric acid, which is effected by the reduction of nitric acid in consequence of the addition of organic substances (lampblack, sawdust, etc.), and of chlorine which is formed by the action of the sulphuric acid upon the common salt. The volume of the dipping bath should not be *too small*, since in pickling the acid mixture becomes heated and the increased temperature shows a very rapid, frequently not controllable, action, so that a corrosion of small articles may readily take place. It is therefore necessary to allow the acid mixture, after its preparation, to thoroughly cool off; pour the sulphuric acid into the nitric acid (never the reverse!!), and allow the mixture, which thereby becomes strongly heated, to cool off to at least the ordinary temperature.

In order to be sure of the uniform action of the pickle upon all parts, it is, in all cases, advisable previous to pickling to free the articles from grease by one of the methods given later on.

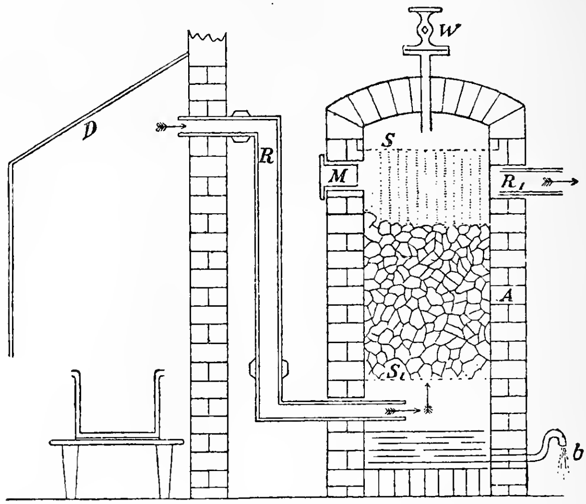
In pickling abundant vapors are evolved which have an injurious effect upon the health of the workmen, and corrode metallic articles exposed to them. The operation should, therefore, be conducted in the open air, or under a well-drawing vapor flue.

In large establishments it may happen that the quantity of escaping acid vapors is so large as to become a nuisance to the neighborhood, which the proprietors may be ordered by the authorities to abate. The evil is best remedied by a small absorbing plant, as follows:—

Connect the highest point of the vapor flue D (Fig. 91) by a wide clay pipe R with a brick reservoir, A, laid in cement, so that R enters A a few centimetres above the level of the fluid, kept at the same height by the discharge pipe b. Above, the reservoir is closed by a vault through which the water conduit W is introduced. Below the sieve S, which is made of wood and coated with lacquer, a wide clay pipe R_1 leads to the chimney of

the steam boiler; or the suction pipe of an injector is introduced in this place by which the air from the vapor flue is sucked through the reservoir and allowed to escape into the open air or into a chimney. Through the manhole *M* the sieve-bottom *S*

Fig. 91.



of the reservoir is filled with large pieces of chalk or limestone, the manner of operating being then as follows: A thin jet of water falls upon *S*, where it is distributed and runs over the laye of chalk. The air of the pickling room saturated with acid vapor moves upward in consequence of the draught of the chimney of the steam boiler, the injector or the ventilator, and yields its content of acid to the layer of chalk, while the neutral solution o calcium nitrate and calcium chloride, which has been formed, runs off through *b*.

The absorption of the acid vapors may, of course, be effected by apparatus of different construction, but the one above described may be recommended as being simple, cheap, and effective.

The considerable consumption of acid for pickling purposes in large establishments makes it desirable to regain the acid and metal contained in the exhausted dipping baths. The following process has proved very successful for this purpose: Mix the old dipping baths with $\frac{1}{4}$ their volume of concentrated sulphuric acid, and

bring the mixture into a nitric acid distilling apparatus. Distil the nitric acid off at a moderate temperature, condense it in cooled clay-coils, and collect it in glass balloons. To the residue in the still add water, precipitate from the blue solution, which contains sulphate of copper and zinc, the copper with zinc waste, and add zinc until evolution of hydrogen no longer takes place. Filter off the precipitated copper through a linen bag, wash and dry. The fluid running off, which contains zinc sulphate, is evaporated to crystallization and yields quite pure zinc sulphate, which may be sold to dye-works, or for the manufacture of zinc-white.

According to local conditions, for instance, if the zinc sulphate cannot be profitably sold in the neighborhood, or zinc waste cannot be obtained, it may be more advantageous to omit the regaining of zinc from the dipping baths. In this case, the fluid which is obtained by mixing the contents of the still with water is compounded with milk of lime until it shows a slightly acid reaction. The gypsum formed is allowed to settle, and after bringing the supernatant clear fluid into another reservoir the copper is precipitated by the introduction of old iron. The first rinsing waters in which the pickled objects are washed are treated in the same manner. The precipitated copper is washed and dried.

For the production of a *grained surface* by pickling, a mixture of 1 volume of saturated solution of bichromate of potash in water and 2 volumes of concentrated hydrochloric acid may be recommended. The brass articles are allowed to remain in the mixture for several hours, when they are momentarily plunged into the bright-dipping bath, and rinsed in a large volume of water, which should be frequently changed.

Removal of grease.—This operation is to be executed with the greatest nicety, because on it chiefly depends the success of eletroplating. Its object is to remove every trace of impurity, be it due to touching with the hands or to the manipulation in grinding and polishing.

According to the preparatory treatment of the objects, the removal of grease is a more or less complicated operation. Large amounts of oily or greasy matter should be removed by rinsing in benzine, it being recommended to execute this operation immediately after grinding and polishing so that the oil used in these

operations has no chance of hardening as is frequently the case with objects polished with Vienna lime and oil. Instead of cleaning with benzine, the objects, as far as their nature allows, may be boiled in a hot lye of 1 part of caustic potash or soda in 10 of water, until all the grease is saponified, when the dirt, consisting of grinding powder, can be readily removed by brushing. In place of solutions of caustic alkalies, hot solutions of potash or soda may be used, but their action is much slower and offers no advantages. Objects of tin, lead, and Britannia, being attacked by the hot lye, must be left in contact with it for a short time only.

The articles thus freed from the larger portion of grease are first rinsed in water, and then for the removal of the last traces of grease brushed with a bristle brush and a mixture of water, quicklime, and whiting, until when rinsing in water all portions appear equally moistened and no dry places are visible.

The lime mixture is prepared by slaking freshly burnt lime, free from sand, with water to an impalpable powder, mixing 1 part of this with 1 of fine whiting, and adding water with constant stirring until a paste of the consistency of syrup is formed.

The shape of many objects presents certain difficulties in the removal of grease; the deeper portions cannot be reached with the brush, as, for instance, in skates, which often are to be nickelled in a finished state. In this case the objects are drawn in succession through three different benzine vessels; in the first benzine most of the grease is dissolved, the rest in the second, while the third serves for rinsing off. When the benzine in the first vessel contains too much grease, it is emptied and filled with fresh benzine, and then serves as the third vessel, while that which was formerly the second becomes the first, and the third the second. After rinsing in the third benzine vessel, the objects are plunged in hot water, then for a few seconds dipped in thin milk of lime, and finally thoroughly rinsed in water. It is recommended not to omit the treatment with milk of lime of objects freed from grease with benzine.

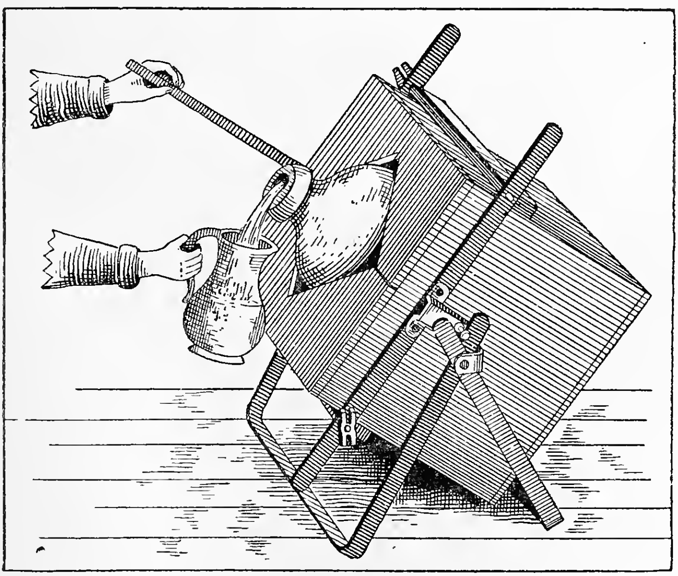
To avoid subsequent touching with the hands the objects, before freeing them from grease, must of course be tied to the metallic wires (of soft copper) by which they are suspended in the electro-

plating bath. In removing the grease by the wet method a layer of oxide scarcely perceptible to the eye is frequently formed upon the metals. This layer of oxide has to be removed, the liquid used for the purpose varying, of course, with the nature of the layer.

Objects of *iron* and *steel* as well as of *zinc* are momentarily plunged in a mixture of sulphuric acid 1 part by weight and water 20 parts, and quickly rinsed off in clean water. Highly polished objects of iron and steel, after being treated with this mixture, are best again rapidly brushed with lime paste, and, after rinsing off quickly, immediately brought into the electro-plating bath.

Copper, brass, bronze, German silver, and tombac are best treated with a dilute solution of potassium cyanide, 1 part of 60

Fig. 92.



per cent. potassium cyanide in 15 to 20 of water. The objects are then quickly rinsed off and placed in the electro-plating bath.

Lead and *Britannia* may be treated with water slightly acidulated with nitric acid.

To overcome the difficult and dangerous operation of carrying and tilting heavy carboys containing acids, the Zucker and Levett Chemical Company, of New York, have introduced a simple device whereby the carrying of carboys becomes easy, and the pouring out of the contents can be done with safety. The illustration, Fig. 92, shows a stand with a carboy placed thereon, partly swung over, as in the act of pouring. It will be seen that while the carboy can be tilted or turned over with ease, and any quantity drawn from it without the danger of spilling, a considerable amount of labor and material can be saved. As seen in the illustration, the carrying bars are fastened or clamped to the carboy by means of two screw-bolts which rest on the cleats of the box. These bars are of such lengths as to project beyond the ends of the box, and provide handles, whereby the carboy may be carried. The stand can be folded up in a compact manner for transportation or storage.

CHAPTER VI.

PROCESSES OF ELECTRO-DEPOSITION.

NEXT to the proper mechanical and chemical preparations of the objects, the success of the process of electro-deposition depends on the suitable composition of the electrolytic solutions (baths), and the correct current-strength which is conducted into the bath for the precipitation of the metals. In regard to the latter the most essential conditions have already been discussed in Chap. IV., "Electro-plating plants in general," and will be further referred to in speaking of the several electro-plating processes. Hence, the general rules which have to be observed in the preparation of the baths will first be considered.

Water being the solvent for all electrolytic baths, its constitution is by no means of such slight importance as is frequently supposed.

Spring and well water often contain considerable quantities of lime, magnesia, common salt, iron, etc., the presence of which may

cause various kinds of separations in the baths; on the other hand, river water is frequently impregnated to such an extent with organic substances that its employment without previous purification cannot be recommended. No doubt, distilled water, or in want of that rain water, is the most suitable for the preparation of baths. However, rain water collected from metal roofs should not be used, nor that running off from other roofs, it being contaminated with dust. Rain water should be caught in vessels of glass, earthenware, or wood, free from tannin, and filtered. Where river or well water has to be employed, thorough boiling and filtering before use are absolutely necessary in order to separate the carbonates of the alkaline earths held in solution. By boiling a possible content of sulphuretted hydrogen is also driven off.

Another important factor is the purity of the chemicals used for the baths, the premature failure of the latter being in most cases caused by the unsuitable nature of the chemicals, which also frequently gives rise to abnormal phenomena inexplicable to the operator. Chloride of zinc, for instance, may serve as an example. It is found in commerce in very varying qualities, it being prepared for dyeing purposes with about 70 per cent. actual content of chloride of zinc, for pharmaceutical purposes with about 90 per cent., and for electro-plating purposes with 98 or 99 per cent. Now it will readily be seen that if an operator in preparing a brass bath according to a formula which calls for pure chloride of zinc uses a preparation intended for dyeing purposes, there will be a deficiency of metallic zinc in the bath, and the content of copper in the bath being too large in proportion to the zinc present, will cause reddish shades in the deposits.

Likewise, in case the operator uses potassium cyanide of low content, when the formula calls for a pure article with 98 per cent., he will not be able to effect the solution of copper or zinc salts with the quantity prescribed. Furthermore, potassium cyanide in the preparation of which prussiate of potash containing potassium sulphate is used, will cause, by reason of the formation of potassium sulpho-cyanide, various disturbing influences (formation of bubbles in the deposit), the explanation of which is difficult to the operator, who, trusting to the purity of the

chemicals, seeks elsewhere for the causes of the abnormal phenomena.

Or, if in preparing nickel baths, a salt containing copper is used, the nickelling will never be of a pure white color, but show shades having not even a distant resemblance to the color of nickel.

The above-mentioned examples suffice to show how careful the operator must be in the selection of the sources from which he obtains his supplies. It may here be mentioned that all the directions given in the following pages refer to chemically pure products; where products of a lower standard may be used the content is especially given.

For the *concentration* of the various baths, no general rules can be laid down; neither can the determination of the density of the baths by the hydrometer be relied on. If the electro-plating solutions consisted of nothing but the pure metallic salts, the specific gravity, which is indicated by the hydrometer-degrees, might serve for an estimation of their value. But such an estimation is often apt to prove deceptive, since to decrease the resistance the baths also require conducting salts, and by the addition of a larger quantity of them the specific gravity of a bath may be increased to any extent without the content of the more valuable metal being greater than in a bath showing fewer hydrometer-degrees.

An electrolytic bath should not be *poor in metal*, as otherwise it soon becomes exhausted, and besides the deposits form more slowly than in a bath with a correct content of metal; on the other hand, the bath must not be too concentrated, as, in this case, salts in the form of crystals readily separate and deposit themselves upon the anodes, the sides of the vessels, and even upon the articles themselves, which may cause holes to form in the deposit; or the crystals envelop the anodes so tightly that the current cannot reach the bath. Besides, too concentrated baths generally produce discolored deposits, as, for instance, too concentrated nickel baths, which yield a dark and spotted deposit.

Hence in summer, when the bath has a higher temperature, it may be made more concentrated than in winter. If crystals are separated out, even when the bath shows a temperature of 58° F.,

it must be diluted with water until the formation of crystals ceases, after those which have been formed have been dissolved in hot water added to the bath.

In order that all strata of the bath may show an equal content of metal, it is advisable in the evening, after the day's work is done, to thoroughly stir up the solution with a wooden crutch. For practical reasons the baths are generally made one-quarter to one-third deeper than corresponds to the lengths of the objects to be plated. In consequence of this, the strata of fluid between the anodes and the objects become poorer in metal than those on the bottom, and the object of stirring up is to restore the same concentration to all portions of the bath.

The strata of fluid which come in contact with the anodes become, by the absorption of metal, specifically heavier than the other strata, and sink to the bottom; on the other hand, the strata of fluid which yield metal to the objects become specifically lighter and rise to the top. A partial compensation of course takes place by diffusion, but not a complete one, and from this cause arise several evils. The heavier and more saturated fluid, offering greater resistance to the current, the anodes are attacked chiefly on the upper portions where the specifically lighter layer of fluid is; practically this is proved by the appearance of the anodes which, at first square, after being for some time used assume the shape shown in Fig. 93.

Fig. 93.

On the other hand, the portions of the cathodes (objects) which come in contact, near the surface, with strata of fluid poorer in metal, acquire a deposit of less thickness than the lower portions which dip into the bath where it is richer in metal. Now, if the bath also contains free acid, and if there is a considerable difference in the specific gravity of the lower and upper strata of fluid, the electrode, which touches both strata, produces a current, the effect of which is that metal dissolves from the upper portions and deposits upon the lower. This explains the phenomenon that a deposit on the upper portions of the objects may be redissolved, even when a current which, however, must be very weak, is conducted into the bath from an external source.

Many authors, therefore, go so far as to demand that during the electro-plating process the baths should be kept in constant agitation by mechanical means. This, however, is scarcely necessary, because a homogeneity of the solution is to a certain extent effected by the agitation of the fluid in suspending and taking out the objects. Hence as long as objects are put in and taken out an agitation naturally takes place in which all the strata of fluid between the objects and anodes take part, while only the deepest strata, which do not come into contact with the objects and the anodes, remain in a state of stagnation.

Constant agitation of the electro-plating solution is of advantage only in silvering and in the galvano-plastic reproduction in the acid copper bath, in which the objects have to remain four to five and eight to ten hours. Some authors demand constant agitation for the more rapid removal of the bubbles of hydrogen which form on the objects; but the same end is attained without complicated contrivances, by the operator accustoming himself to strike the object-rod a slight blow with the finger each time he suspends an object.

The degree of temperature required for the electro-plating solutions has already been discussed on page 76, where also the means have been given by which too cool solutions may be brought to the proper degree of temperature. Baths which are to be used cold should under no circumstances show a temperature below 59° F., it being best to maintain them at between 64.5° and 68° F.

Boiling is required in the preparation of many baths, if, after

Fig. 94.

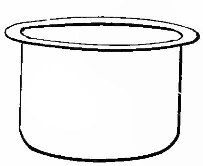
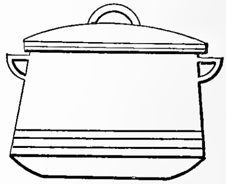


Fig. 95.



cooling, they are to yield good and certain results. The kettles and boiling-pans used for the purpose are of various shapes, hemispherical or with flat bottom, and are made of different materials (Figs. 94 and 95), those of enamelled iron, or, for small baths, of porcelain or earthenware, being best. The enamel of

the iron kettles must be of a composition which is not attacked by the bath. Notwithstanding their enamel these vessels become gradually impregnated with the solutions they have held, and it is dangerous to employ them for different kinds of baths. Thus, an enamelled kettle which has been used for silvering will not be suitable, even after the most thorough washing, for a gold bath, as the gilding will certainly be white or green, according to the quantity of silver retained by the vessel. The use of metal vessels should be avoided; copper and brass baths may, however, be boiled in strong copper kettles, though they are somewhat attacked. A copper kettle, after being freed from grease and scoured bright, may be provided with a thick deposit of nickel, by filling it with a nickel bath, connecting it with the negative pole of a strong battery or dynamo machine, and suspending in it a number of nickel anodes connected with the positive pole. Such nickelled kettle may be used for boiling nickel baths, but enamelled kettles or large dishes of nickel-sheet deserve the preference.

If the boiling of large quantities of fluid is not convenient, the same end may be attained by thoroughly working the bath for a few days with the electric current. Suspend to the anode-rods as many anodes as possible, secure to the object-rods a few plates of the same metal, and introduce a current of medium strength, until an object, from time to time, suspended in the bath acquires a regular deposit. This method is frequently and very successfully used for large brass baths.

If nickel salts, dissolving with difficulty, have to be dissolved for the preparation of nickel baths, and a suitable kettle for the purpose be wanting, boil clean water in a brightly-scoured copper kettle; pour the boiling water into a clean wooden bucket holding from eight to ten quarts; add the corresponding quantity of nickel salt, and stir with a stick of wood until solution is complete.

For large baths this method consumes too much time, and it is better to use a large oval or round wooden vat, which is provided with a coil of lead, and to bring the contents of the vat to boiling by introducing steam into the coil.

If the prepared and boiled solutions are not entirely clear, they have to be filtered, which for large baths is best effected

with bags of fine felt; and for smaller baths, especially those of the noble metals, with filtering paper.

To secure *lasting qualities* to the baths, they must be carefully protected from every possible contamination. When not in use for plating they should be covered to keep out dust. The objects before being placed in the baths should be free from adhering scouring material or dipping fluid, which otherwise might, in time, spoil the bath. The cleansing of the anode and object rods by means of sand paper, or emery paper, should never be done over the bath, so as to avoid the danger of the latter being contaminated by the oxides of the metal constituting the rods falling into it. When a visible layer of dust has collected upon the bath, it must be removed, as otherwise particles of dust might deposit upon the articles and prevent an intimate union of the deposit with the basis-metal. With large baths the removal of the layer of dust is readily effected by drawing a large piece of filtering or tissue paper over the surface, and repeating the operation with fresh sheets of clean paper until all the dust is removed. Small baths should be filtered.

The choice of anodes is also an important factor for keeping the baths in good condition, as well as for obtaining good results. The anodes should always consist of the metal which is deposited from the solution; and the metal used for them must be *pure* and free from all admixtures. To replace as much as possible the metal withdrawn from the bath by the electro-plating process, the anodes must be soluble; and it is wrong if, for instance, nickel baths are charged with insoluble anodes of carbon; or for smaller baths, of sheet platinum. Such insoluble anodes cause a steady and rapid declination in the content of metal, an excessive formation of acid in the bath, and, by the detachment of particles of carbon, a contamination of the solution. Further particulars in regard to anodes will be given in discussing the separate baths.

When upon a pure metallic surface another metal is electro-deposited, the first portion of the deposit penetrates into the *basis-metal*, thus forming an alloy. This may be readily proved by repeating Gore's experiments: If a thick layer of copper be precipitated upon a platinum sheet, and then heated to a dark red heat, the deposit can be entirely peeled off; by then heating the

platinum sheet with nitric acid, and thoroughly washing with water, it appears, after drying, entirely white and pure. By reheating the sheet, the surface becomes again blackened by cupric oxide, and by frequently repeating the same operation a fresh film of cupric oxide will always be obtained.

This penetration of the deposit into the basis-metal, however, does not merely take place during electro-plating but also later on, and it may frequently be observed that, for instance, zinc objects only slightly coppered or brassed, after some time become again white. Since this also happens when the deposits are protected by a coat of lacquer against atmospheric influences, the only explanation of the phenonenon can be that the deposit is absorbed by the basis-metal, which is also confirmed by analysis. This fact must be taken into consideration if durable deposits are to be produced.

To guarantee good performance an electro-plating bath must fulfil the following conditions :—

1. It must possess good working capacity.
2. It must exert a sufficiently dissolving action upon the anode.
3. It must reduce the metal in abundance and in a reguline state.
4. It must not be chemically decomposed by the metals to be plated, hence not by simple immersion ; the adherence of the deposit to the basis-metal being in this case impaired.
5. It must not be essentially decomposed by air and light.

Reduction of metals without a battery (*electro-deposition by contact*).

We may here appropriately mention the reduction of metals which takes place by the *contact of two metals in a fluid* without the aid of an exterior source of current. That an electric current is thereby generated has been previously explained: one metal, by coming in contact with a more electro-positive one, becomes electro-negative and decomposes the fluid. If the latter is a metallic solution, and the metal contained in it not more strongly electro-negative than the negatively excited metal, a separation of metal takes place in consequence of decomposition. *This process is termed electro-deposition by contact.* Generally the metals

which are to be coated are brought in contact with a bright rod of zinc, the latter being a highly electro-positive metal. The zinc is allowed to dip in only so far as to secure a sure contact with the metal to be coated.

The contact of one metal with *two fluids*, or that of *two metals in two fluids*, presents similar phenomena; an electric current with visible action manifests itself, and in the latter case we have a complete element. By dipping the more electro-negative metal in a metallic solution whose metal is not more electro-negative, the metal separates from the solution upon the metallic strip dipping

Fig. 96

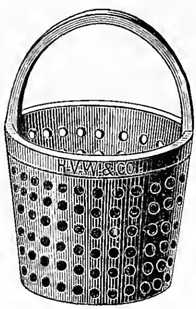


Fig. 97.

Fig. 98.

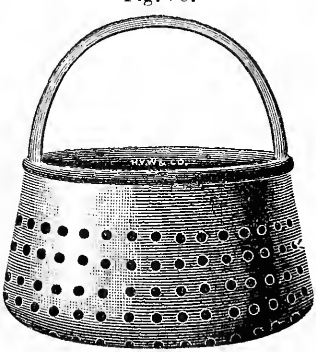
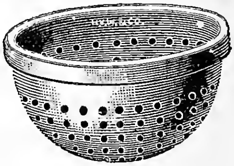


Fig. 99.



in. While by the contact of one metal with another in one fluid, only thin deposits can be produced, and by coating the electro-negative metal with the separated metal the contact-current loses some of its original strength, by immersing two metals in two

fluids, depositions of considerable thickness can under certain conditions be produced, as, for instance, with the galvano-plastic cell apparatus, which will be discussed later on.

A reduction of metal can also be brought about by dipping *one* metal into *one* fluid. This may take place in consequence of the simple solution of the metal dipped in, and hence the separation may be conceived as a simple chemical action. In how far electric currents manifest themselves and co-operate thereby is still undecided; we only know that the electro-positive metals, such as zinc, tin, iron, copper, can reduce the electro-negative metals, such as mercury, silver, gold, etc., from the solutions of their salts, and that the reduction is the more rapid and the stronger the more electro-positive is the metal dipped in, and the more electro-negative the dissolved metal.

Upon this action depend coppering, silvering, gilding, etc., by immersion.

For dipping large numbers of small articles at a time *dipping-baskets* are used. Figs. 96 to 99 represent different forms of glazed stone-ware dipping-baskets such as are generally employed, though some platers prefer a platinum gauze cage.

CHAPTER VII.

DEPOSITION OF NICKEL AND COBALT.

1. *Nickelling.*

THOUGH nickel-plating is of comparatively recent origin, it shall be first described, since chiefly by reason of the development of the dynamo-electrical machine it has steadily grown in popularity and become an industry of great magnitude and importance. The great popularity which nickel-plating enjoys is due to the excellent properties of the nickel itself: the almost silvery whiteness of the metal, its cheapness as compared with silver, and the hardness of the electro-deposited metal, which give the coating great power to resist wear and abrasion, its capability of taking a high polish; the fact that it is not blackened by the action

of sulphurous vapors which rapidly tarnish silver, and finally the fact that it exhibits but little tendency to oxidize even in the presence of moisture.

Properties of nickel.—Pure nickel is a lustrous, silvery white metal with a slight steel gray tinge. It is hard, malleable, and ductile. Its specific gravity varies from 8.3 (cast nickel plates) to 9.3 (wrought or rolled plates). It melts at about the same temperature as iron, but is more fusible when combined with carbon. It is slightly magnetic at ordinary temperatures, but loses this property on heating to 680° F.

The metal is soluble in dilute nitric acid, concentrated nitric acid rendering it passive, *i. e.*, insoluble. In hydrochloric and sulphuric acids it dissolves very slowly, especially when in a compact state.

Certain articles, for instance, hot fats, strongly attack nickel, while vinegar, beer, mustard, tea, and other infusions produce stains; hence, the nickelling of culinary utensils or the use of nickel-plated sheet-iron for culinary utensils cannot be recommended.

The chemical equivalent of nickel is 29.5

Nickel baths.—The first requisite in preparing nickel baths is the use of absolutely pure chemicals, and in choosing the nickel salts to be especially careful that they are free from salts of iron, copper, and other metals. Furthermore, it is not indifferent what kind of nickel salt is used, whether nickel chloride, nickel sulphate, the double sulphate of nickel and ammonium, etc., but the choice of the salt depends chiefly on the nature of the metal which is to be nickelled. There are a large number of general directions for nickel baths, of which nickel chloride, ammonio-nickel chloride, nickel nitrate, etc., form the active constituents, and yet it would be a grave mistake to use these salts for nickelling iron, because the liberated acid, if not immediately and completely fixed by the anodes in dissolving, imparts to the iron objects a great tendency to the formation of rust. Iron objects nickelled in such a bath, to be sure, come out faultless, but in a short time, even if stored in a dry place, portions of the nickel layer will be observed to peel off, and by closely examining such objects it will be seen that under the deposit of nickel a layer of

rust has formed which actually tears the nickel off. The use of nickel sulphates or of the salts with organic acids is, therefore, considered best. It might be objected that the liberated sulphuric acid produces in like manner a formation of rust upon the iron objects, but according to long experience and many thorough examinations such is not the case, the tendency to the formation of rust being only imparted by the use of the chloride and nitrate. The use of nickel salts with organic acids is in many cases more advantageous than that of the sulphates, but such salts are considerably dearer, and hence they are less frequently employed; in many *prepared nickelling salts* they form the active constituent. The composition of the *conducting salts* requires the same deliberation as that of the nickelling salts. To decrease the resistance of the nickel solutions, conducting salts are added to them, which are also partially decomposed by the current. Like the use of nickel chloride in nickelling iron, an addition of ammonium chloride, which is much liked, cannot be recommended, though the subsequent easy reduction of nickel invites its employment.

For copper and its alloys, zinc, etc., the chlorine combinations may be used, but for nickelling iron they must be avoided as the source of future evils. The use of sodium sulphide, sodium nitrate, barium oxalate, ammonium nitrate, sodium sulphate, and ammonium-alum as conducting salts, which has been recommended by various authors, is unsuitable. With few exceptions, which will be given later on, the best basis for the conducting salt, according to Böttger and Adams, is ammonia, especially in the form of ammonium sulphate or hydrochlorate, provided the latter is not used for baths for nickelling iron.

Some other additions to the nickelling bath which are claimed to effect a pure silvery-white reduction of the nickel have been recommended by various experts. Thus, the presence of small quantities of an organic acid has been proposed; for instance, boric acid by Weston, benzoic acid by Powell, and citric acid or acetic acid by others. The presence of small quantities of a *free acid* effects without doubt the reduction of a *whiter* nickel than is the case with a neutral or alkaline solution. Hence a *slightly* acid reaction of the nickelling bath, due to the presence of citric acid, etc., with the exclusion of the strong acids of the metal-

loids, can be highly recommended. The quantity of free acid must, however, not be too large, as this would cause the deposit to peel off.

Boric acid, recommended by Weston as an addition to nickelling and all other baths, has a favorable effect upon the pure white reduction of the nickel, especially in nickelling rough castings, *i. e.*, surfaces not ground. Weston claims that boric acid prevents the formation of basic nickel combinations on the objects, and that it makes the deposit of nickel more adherent, softer, and more flexible. Whether with a correct current-strength, basic nickel salts, to which the yellowish tone of the nickelling is said to be due, are separated on the cathode, is not yet proved, and would seem more than doubtful. The action of the boric acid has not yet been scientifically explained, but numerous experiments have shown that the deposition of nickel from nickel solution containing boric acid is neither more adherent nor softer and more flexible than that from a solution containing small quantities of a free organic acid. Just the contrary, the deposition is harder and more brittle in the presence of boric acid, and different results may very likely be due to the employment of currents of varying strength. A *weak* current always and under all conditions causes the deposition of a *harder* and *more brittle* nickel than a current of medium strength, and in order to judge the quality of the deposited nickel from baths of varying composition, the surface of the objects and of the anodes must always be the same, and currents of equal quantity and electro-motive force be conducted into the bath. Weston's bath will be spoken of later on. Powell's proposition for the use of benzoic acid need scarcely be taken seriously, since the results from baths containing it differ in no respect from those without it.

Before giving suitable formulæ for the composition of nickel baths, it will be necessary to discuss the means of determining their acidity and alkalinity. As previously mentioned, a nickel bath, to yield a beautiful white deposit, should contain only a small quantity of free acid; too much acid preventing the firm adherence of the deposit, while alkaline and even neutral baths do not yield nickel of a pure white color, but of a somewhat darker tone. A bath is *neutral* when it contains neither free acid

nor free alkali, which is recognized by neither blue nor red litmus-paper* being changed by the solution. Blue litmus-paper is colored red by acid fluids, and red litmus-paper blue by alkaline fluids. By simultaneously dipping one-half of a strip of blue and of red litmus-paper in the solution, the reaction of the fluid can be judged from the change in color and the rapidity and intensity of its appearance. If a bath which, like most nickel baths, is to work with only a slight reaction, immediately and intensely reddens blue litmus-paper, a suitable alkali has to be added until the coloration of a fresh strip of litmus-paper appears slower and less intense. If, on the other hand, the test shows that red litmus-paper becomes blue, and that consequently the bath is alkaline, a slight acid reaction is restored by the gradual addition of citric acid or another acid suitable to the composition of the bath. Baths made with boric acid form an exception, and must work with a strong acid reaction.

I. The most simple nickel bath consists of a solution of 8 to 10 parts by weight of pure nickel ammonium sulphate in 100 parts by weight of distilled water. If too acid, the solution is neutralized with spirits of sal ammoniac to a slightly acid reaction. The solution is prepared by boiling the salt with the corresponding quantity of water, using in summer 10 parts of nickel salt to 100 of water, but in winter only 8 parts, to prevent the nickel salt from crystallizing out. This bath, which is frequently used, possesses, however, a considerable degree of resistance to conduction, and hence requires a strong current for the deposition of the nickel. It also requires cast nickel anodes, since with the use of rolled anodes nickelling proceeds in a very sluggish manner. However, the cast anodes rapidly render the bath alkaline, necessitating a frequent correction of the reaction. To decrease the resistance, recourse has been had to certain *conducting salts*, and, below, the more common nickel baths will be discussed, together with their mode of preparation and action, as well as their availability for certain purposes.

II. Nickel ammonium sulphate 17 ozs., ammonium sulphate 17 ozs., distilled water 10 quarts.

* Blue and red litmus-paper must be kept, each by itself, in well-closed glass jars.

Boil the salts with the water, and, if the solution is too acid, restore its neutrality by spirits of sal ammoniac; then gradually add solution of citric acid until blue litmus-paper is slowly but visibly reddened. The bath deposits rapidly, it possessing but little resistance; an electro-motive force of 1.8 to 2 volts suffices, and all metals (zinc, lead, tin, and Britannia, after previous coppering) can be nickelled in this bath. However, upon rough castings and iron a pure white deposit is difficult to obtain, frequent scratch-brushing with a medium hard steel brush being required. On account of the great content of sulphate of ammonium in the bath, the nickel deposit piles up especially on the lower portions of the objects, which, in consequence, readily become dull (*burn or over-nickel,* for which see later on), while the upper portions are not sufficiently nickelled. For this reason the objects must be frequently turned in the bath so that the lower portions come uppermost. This piling up of the deposit also frequently prevents the latter from acquiring a uniform thickness.

III. Nickel ammonium sulphate 25½ ozs., ammonium sulphate 8 ozs., crystallized citric acid 1¾ ozs., water 10 to 12 quarts.

This bath is prepared in the same manner as the preceding, the salts being dissolved in boiling water, and ammonia added until blue litmus-paper is only slightly reddened.

This bath requires a somewhat greater electro-motive force than the preceding, or about 2 to 2.2 volts. The formation of the nickel deposit is, however, more uniform, of a beautiful white color, dense and hard, and consequently bears polishing without danger of the nickel grinding off, even if not very thickly plated. It is very suitable for nickelling ground surgical instruments, as well as all ground iron articles which are to be thickly and solidly plated, and for heavy, solid nickelling of copper, brass, bronze, etc. It is much used in this country, either with or without the addition of citric acid.

If, after working for some time, the bath loses conducting power, the objects, with the use of the proper current, become blackish without a reduction of nickel being perceptible; while with a stronger current the objects are nickelled white, but the deposit readily peels off. In this case the conducting power has to be increased by the addition of ammonium sulphate.

The bath should always be kept so that it shows a slightly acid reaction. It is best to use rolled anodes.

IV. Nickel ammonium sulphate 23 ozs., ammonium chloride (crystallized) 11½ ozs., water 10 to 12 quarts.

The bath is prepared in the same manner as given for II. and III. It nickels very rapidly and quite white, but the deposit is soft, and hence care must be had in polishing upon cloth or felt bobs, the corners and edges of the objects especially requiring careful handling. On account of the danger of peeling off, a heavy deposit of nickel cannot be obtained in this bath, since, in consequence of the rapid precipitation, the deposit condenses and absorbs hydrogen, is formed with a coarser structure, and turns out less uniform and dense. These phenomena are a hindrance to a heavy deposit, which, if it is to adhere, must be homogeneous and dense. As previously mentioned, *baths with the addition of chlorides as well as those prepared with nickel chloride and nickel nitrate are not suitable for the solid nickelling of iron;* they are, however, well adapted to the rapid light nickelling of *cheap brass articles.* The electro-motive force required for this bath is 1.8 volts.

V. Nickel chloride (crystallized) 17½ ozs., ammonium chloride (crystallized) 17½ ozs., water 12 to 15 quarts.

The bath is prepared in the same manner as given for II. and III., though solution may be effected cold. The bath precipitates very readily, and is especially liked for nickelling zinc castings. Tension of current, 1.5 to 1.75 volts.

For nickelling iron this bath has the same disadvantages, and even to a still greater extent than the preceding.

VI. *Baths containing boric acid.*—Weston recommends the following composition for nickel baths: Nickel chloride 17½ ozs., boric acid 7 ozs.; water 20 quarts, *or*, nickel-ammonium sulphate 35 ozs., boric acid 17½ ozs., water 25 to 30 quarts. Both solutions are said to be improved by adding caustic potash or caustic soda so long as the precipitate formed by the addition dissolves.*

These compositions, however, cannot be recommended, chiefly because the baths work faultlessly for a comparatively short time only; all kinds of disturbing phenomena make their appearance,

* Dingler's Journal, 235, p. 404. Wagner's Jahresbericht, 1883, p. 146.

the deposit being no longer white but blackish, and the baths soon failing entirely. Kaselowsky's formula yields similar results. It is prepared by dissolving, with the assistance of heat, $35\frac{1}{4}$ ozs. of nickel-ammonium sulphate and $17\frac{3}{8}$ ozs. of boric acid in 20 quarts of water. If an *entirely neutral* double sulphate has not been employed, this bath also generally fails after two or three months' use. By taking the ordinary nickel salt, which is crystallized from an acid solution and employing rolled nickel anodes, the bath will certainly have to be thrown away after using it at the utmost for three months.

Such a bath, with boric acid, however, works satisfactorily by proceeding as follows :—

VII. Nickel-ammonium sulphate 21 ozs., chemically pure nickel carbonate $1\frac{3}{4}$ ozs., chemically pure crystallized boric acid $10\frac{1}{2}$ ozs., water 10 to 12 quarts.

Boil the nickel-ammonium sulphate and the nickel carbonate in the water until the development of bubbles of carbonic acid ceases and blue litmus-paper is no longer reddened; then add the boric acid, and after allowing the whole to boil a few minutes longer cool and filter. The reaction of the solution is *strongly acid* and must not be removed by alkaline additions. A bath thus prepared lasts at least twice as long as one which is prepared without previous neutralization of the double nickel salt by nickel carbonate. The treatment of the bath varies according to whether rolled or cast anodes are used; in the first case free sulphuric acid readily forms, the consequence of which will be an exfoliating reduction of nickel with a simultaneous strong evolution of hydrogen on the objects. The bath must then be compounded with an addition of alkali (except spirit of sal ammoniac) corresponding to the quantity of free sulphuric acid. With the use of cast anodes the bath readily becomes alkaline, and requires the restoration of the acid reaction, since a bath containing boric acid, which has become alkaline, also nickels gray-black and dull, even when the deposit has acquired only slight thickness. It is, therefore, best to work with mixed anodes, *i. e.*, rolled and cast.

A bath prepared according to the above formula requires an electro-motive force of about 2.5 volts; while working, the resist-

ance of the solution increases somewhat and reaches its maximum in 3 or 4 weeks, when it remains constant. All baths prepared with an addition of boric acid exhibit the property of their resistance growing with comparative rapidity in the beginning, but not increasing after having reached a certain limit.

Below are given a few other formulæ for nickel baths which may be advantageously used for *certain purposes*, but not for nickelling all kinds of metals.

VIII. Nickel sulphate $10\frac{1}{2}$ ozs., potassium citrate 7 ozs., ammonium chloride $10\frac{1}{2}$ ozs., water 10 to 12 quarts.

To prepare the bath dissolve $10\frac{1}{2}$ ounces of nickel sulphate and $3\frac{1}{2}$ ounces of pure crystallized citric acid in water; neutralize accurately with caustic potash, and then add the ammonium chloride. This bath is especially adapted for the rapid nickelling of *polished, slightly coppered zinc* articles. The deposition is effected with a very feeble current, without the formation of black streaks, such as are otherwise apt to appear in nickelling with a weak current. The deposit itself is dull and somewhat gray, but acquires a very fine polish and pure white color by slight manipulation upon the polishing wheels. With a stronger current the bath is also suitable for the direct nickelling of zinc articles; it must, however, be kept strictly neutral. The bath works with rolled anodes, and but seldom requires a correction of the reaction.

IX. Nickel phosphate $8\frac{1}{2}$ ozs., sodium pyrophosphate $26\frac{1}{4}$ ozs., water 10 to 15 quarts. Dissolve the sodium pyrophosphate in water, heat the solution to about 167° F. and add the nickel phosphate with constant stirring. Nickel phosphate is obtained as a pale green powder by precipitating solution of nickel sulphate with sodium phosphate.

This bath yields a very fine dark nickelling upon *iron, brass*, and *copper*, as well as *directly*, without previous coppering, upon *sheet zinc* and *zinc castings*, and may be advantageously used for decorative purposes where darker tones of nickel are demanded.

X. A fairly good nickel-bath for electro-platers having but a feeble current at their disposal is obtained from a solution of nickel-ammonium sulphate $22\frac{1}{2}$ ozs., magnesium sulphate $11\frac{1}{4}$ ozs., water 10 to 12 quarts.

This bath precipitates readily and strongly, and a heavy coating

can also be deposited upon *iron* without fear of the disagreeable consequences of bath IV.; even *zinc* may be directly nickelled in it with a comparatively feeble current. The deposit, however, turns out rather soft, with a yellowish tinge, and the bath does not remain constant, but fails after working at the utmost three or four months, the anodes being scarcely attacked.

Below are given the compositions of a few nickel baths which have recently been highly recommended:—

XI. Pure nickel sulphate $35\frac{1}{2}$ ozs., neutral ammonium tartrate $26\frac{1}{2}$ ozs., tannin 77 grains, water 20 quarts. Neutral ammonium tartrate is obtained by saturating a solution of tartaric acid with ammonia. The nickel salt must also be neutral. For this purpose dissolve the above-mentioned ingredients in 3 or 4 quarts of water and boil the solution for $\frac{1}{4}$ hour, then add enough water to make 20 quarts of fluid, and filter. The bath is said to yield a very white, soft, and homogeneous deposit of any desired thickness, without roughness or danger of peeling off. On rough or polished castings thick deposits may be obtained at a cost scarcely exceeding that of coppering. Galvanoplastic reproduction may also be effected in this bath. For those who wish to try the bath it may be mentioned that the most suitable current-strength is 3.5 volts.

XII An English formula is as follows: Dissolve $17\frac{1}{2}$ ozs. of nickel sulphate, $9\frac{1}{4}$ ozs. of tartaric acid, and $2\frac{1}{4}$ ozs. of caustic potash in 10 quarts of water.

The addition of bisulphide of carbon to nickel baths, which has recently been recommended by Bruce, is not advisable. According to Bruce, such an addition prevents the nickel deposits from becoming dull when reaching a certain thickness, but repeated experiments made strictly in accordance with the directions given did not confirm this statement.

XIII. For nickelling small articles the following bath is claimed to yield excellent results: Nickel-ammonium sulphate 64 ozs., ammonium sulphate $20\frac{1}{4}$ ozs., crystallized citric acid $4\frac{1}{2}$ ozs.

In some works on galvanoplasty a solution of nickel cyanide in potassium cyanide is recommended for nickelling, but experiments failed to obtain a proper reduction of nickel.

We would here add the general remark that *freshly prepared* nickel baths mostly work correctly from the beginning, though it

may sometimes happen that the articles first nickelled come from the bath with a somewhat darker tone. In such case it is advisable to suspend a few anodes to the cathode and allow the bath to work one or two hours, when the nickelling will proceed faultlessly.

A few words may here be said in regard to what may be termed a *nickel bath without nickel salt.* It simply consists of a 15 to 20 per cent. solution of ammonium chloride, which transfers the nickel from the anodes to the articles; cast anodes are almost exclusively used for the purpose, and deposition may be effected with quite a feeble current. Before the solution acquires the capacity of depositing, quite a strong current has to be conducted through the bath until the commencement of a proper reduction of nickel. This bath is only suitable for *coloring* very cheap articles, it not being possible to produce solid nickelling with it, and it is here mentioned because it may serve as a representative of a series of other electro-plating baths in which the transfer of the metal is effected by sal ammoniac solution without the use of metallic salts, for instance, iron, zinc, cobalt, etc.

Nickel anodes.—Either *cast* or *rolled* nickel plates are used as anodes, which must of course be as pure as it is possible to obtain them. Every impurity of the anodes passes into the bath and jeopardizes its successful working. If too thin, the anodes increase the resistance; for small baths rolled anodes 0.079 inch thick are generally used, and as a rule they should not be less than 0.039 inch thick. For larger baths it is better to use plates from 0.11 to 0.19 inch thick, while the thickness of cast anodes may vary between 0.11 and 0.39 inch, according to the size of the bath and the purpose for which it is to be used. The use of *insoluble* anodes of gas-carbon or platinum, either by themselves or in conjunction with nickel anodes, as frequently recommended, is not advisable. The harder and the less porous the nickel anode is, the less it is attacked in the bath and the less it fulfills the object of keeping constant the metallic content of the solution. On the other hand, the softer and the more porous the anode is, the more readily it dissolves, because it conducts the current better and presents more points of attack to the bath; and the more it is dissolved, the more metal is conveyed to the bath. With the

sole use of rolled anodes and working with a feeble current, free acid is formed in the bath; on the other hand, by working with cast anodes alone, the bath readily becomes alkaline. Now it seems that the possibility of a bath also becoming alkaline even with the sole use of rolled anodes, especially when working with a strong current, has led to the proposal of suspending in the bath, besides the nickel anodes, a sufficient number of insoluble anodes in order to effect a constant neutrality of the bath. It would lead too far to go into the theory of the secondary decompositions which take place in a nickel bath, to prove that, though neutrality is obtained, it can only be done at the expense of the metallic content of the bath. Hence, this impracticable proposal shall here be overthrown by practical reasons, it only requiring to be demonstrated that in baths becoming alkaline the content of nickel also decreases steadily though slowly. This fact in itself shows that in order to save the occasional slight labor of neutralizing the bath, the decrease of the metallic content should not be accelerated by the use of insoluble anodes. For larger baths the use of expensive platinum anodes as insoluble anodes need not be taken into consideration, because for large surfaces of objects correspondingly large surfaces of platinum anodes would have to be present, as otherwise the resistance of thin platinum sheets would be considerable. But such an expensive arrangement would be justifiable only if actual advantages were obtained, which is not the case, because, though the platinum does absolutely not dissolve, the deficiency of metallic nickel in the bath caused by such anodes must be in some manner replaced. The insoluble anodes of *gas-carbon* which have frequently been proposed are attacked by the bath; particles of carbon becoming constantly detached, and floating upon the bath, deposit themselves upon the objects and cause the layer of nickel to peel off. Furthermore, by the use of nickel anodes in conjunction with carbon anodes, the current, on account of the greater resistance of the latter, is forced to preferably take its course through the metallic anodes, in consequence of which the articles opposite the nickel anodes are more thickly nickelled than those under the influence of the carbon anodes. With larger objects this inequality in the thickness of the deposit is again a hindrance to

obtaining layers of good and uniform thickness such as are required for solid nickelling. According to long practical experience, the best plan is to use *rolled and cast anodes* together in one bath. The proportion of cast to rolled anodes depends on the composition of the bath, but it may be laid down as a rule, that baths with greater resistance require more cast anodes, and baths with less resistance more rolled anodes. Cast anodes, to be sure, have the disadvantage of soon becoming spongy, and crumbling before being entirely used up. Furthermore, the surfaces of nickel anodes cast in iron moulds are so hard as to temporarily resist the action of the bath, while the interior dissolves only partially, since, on the one hand, the oxygen separating on the anode, which is necessary for solution, escapes partially unused, and on the other, the intact outer layer prevents the bath from coming in contact with the interior of the anode.

The cast anodes suspended to the ends of the conducting rods are especially strongly attacked, and, therefore, when rolled and cast anodes are used together, it is best to suspend the latter more towards the centre, and the first on the ends of the rods.

These disadvantages, however, are not sufficient to prevent the use of a combination of cast and rolled anodes when required by the composition of the bath. The spongy remnants are thoroughly washed in hot water, dried and sold.

The *rolled nickel anodes* are less liable to corrosion, and may be used up to the thickness of a sheet of paper before they fall to pieces. It is, however, best to replace them by fresh anodes before they become too thin, since with the decrease in thickness their resistance increases.

The surface of the anodes suspended in the baths should be *at least* as large as that of the articles to be nickelled; it is however preferable that they should present twice or three times the surface, in order that the bath may be kept thoroughly saturated with nickel.

It is best to allow the anodes to remain quietly in the bath, even when the latter is not in use, they being in this case not attacked. By frequently removing and replacing them they are subject to concussion, in consequence of which they crumble much more quickly than when remaining quietly in the bath.

In the morning, before nickelling is commenced, the anodes will frequently show a *reddish* tinge, which is generally ascribed to a content of copper in the bath or in the anodes. This reddish coloration also appears when an analysis shows the anodes as well as the bath to be absolutely free from copper. It is very likely due to a small content of cobalt, from which nickel anodes can never be entirely freed. It would seem that by the action of a feeble current cobaltous hydrate is formed, which however immediately disappears on conducting a strong current through the bath.

The anodes are supported by nickel wire 0.11 to 0.19 inch thick or by strips of nickel sheet riveted on.

If after working for some time a nickel bath has become alkaline, which can be readily determined by testing with litmus-paper, its neutrality or a slightly acid reaction can be restored in a few minutes by the addition of either citric, sulphuric, acetic, or boric acid, according to the composition of the bath. On the other hand, when the bath contains too much free acid, it is removed by the addition of spirits of sal ammoniac, ammonium carbonate, potash, or by boiling with nickel carbonate, the choice of the remedy depending on the composition of the bath.

The process of electro-nickelling.—Next to the correct composition of the bath and the proper selection of the anodes, the success of the nickelling process depends on the *thorough cleansing of the objects* and *the correct current-strength.*

The directions for the removal of grease, etc., given on p. 131, also apply to objects to be nickelled. In executing the manipulations, it should always be borne in mind that though dirty, greasy parts become coated with nickel, the deposit immediately peels off by polishing, because an intimate union of the deposit with the basis-metal is effected with only perfectly clean surfaces. Touching the cleansed articles with the *dry* hand must be strictly avoided; but, if large and heavy objects have to be handled, the hands should first be freed from grease by brushing with lime and rinsing in water, and be kept wet.

As previously mentioned, the cleansed objects must not be exposed to the air, but immediately placed in the bath, or, if this is not practicable, be kept under clean water.

While copper and its alloys (brass, bronze, tombac, German silver, etc.), as well as iron and steel, are directly nickelled, zinc, tin, Britannia, and lead are generally first coppered or brassed. With a suitable composition of the nickel bath and some experience, the last-mentioned metals may also be directly nickelled, but, as a rule, previous coppering or brassing is preferable, the certainty and beauty of the results being thereby considerably increased.

Many operators prefer coppering or brassing steel and iron articles before nickelling, and claim that by so doing better protection against rust is secured. While experiments have shown that with the thin coat of copper or brass generally applied this claim is scarcely tenable, the previous coppering of iron objects has the advantage that, in case they have not been thoroughly cleansed, the deposit of nickel is less liable to peel off, the alkaline copper bath completing the removal of grease, but with objects carefully cleansed according to the directions given on p. 126 previous coppering is not necessary.

The objects should never be suspended in the bath without current, the baths, with few exceptions, exerting a chemical action upon many metals which is injurious to the electro-plating process, and especially with the nickel bath is it necessary to connect the anode-rods and object-rods before suspending the articles in the bath.

The *suitable current-strength* has already been fully discussed on p. 76 *et seq.* ("Electro-plating Arrangements in Particular"), and referring the reader to that section we may here be comparatively brief.

In that section it has been said that the surfaces of objects to be nickelled must be in due proportion to the effective zinc surface of the battery if the latter be used for generating the current; further, the surface of anodes suspended in the bath must be at least equal to that of the objects, though in most cases it is better that it should be larger. On p. 17 *et seq.*, it has also been explained how, according to circumstances, the elements have to be coupled to a battery in order to be sure of success. Two Bunsen elements, coupled one after the other, yield for nearly all nickel baths the electro-motive force required for the reduction of the nickel; for baths with great resistance it will, however, be better, especially when the filling of the elements is no longer fresh, to

couple three elements one after the other, and to neutralize a momentary excess of current by the resistance board.

An error is frequently committed in nickelling with too strong a current, the consequence being that the deposit on the lower portions of the objects soon becomes dull and gray-black, while the upper portions are not sufficiently nickelled. This phenomenon, which is due to the reduction of the nickel with a coarse grain in consequence of too powerful a current, is called *burning* or *over-nickelling*. A further consequence of nickelling with too strong a current is that the deposit readily peels off after it reaches a certain thickness. This phenomenon is due to the hydrogen being condensed and retained by the deposit, which is thereby prevented from acquiring greater thickness.

Especially do those objects suspended on the ends of the rods nickel with great ease; this evil can be avoided by hanging on both ends of the rods a strip of copper-sheet about 0.39 inch wide, and of a length corresponding to the depth of the bath.

The following criteria may serve for judging whether the nickelling progresses with a correct current-strength: In two or at the utmost three minutes all portions of the objects must be perceptibly coated with nickel, but without a violent evolution of gas on the objects; small gas bubbles rising without violence and with a certain regularity are an indication of the operation progressing regularly. If, after two or three minutes, the objects show no deposit, the current is too *weak*, and in most cases the objects will have acquired dark, discolored tones. In such case either a stronger current must be introduced by means of the resistance board, or, if the entire volume of current generated already passes into the bath, the object-surface has to be diminished, or, if this is not desired, the battery must be strengthened by adding more elements, or by fresh filling, etc.

If, on the other hand, a violent evolution of gas appears on the objects, and the latter are well covered in a few seconds, and the at first white and lustrous nickelling changes in a few minutes to a dull gray, the current is *too strong*, and must be weakened either by the resistance board, or uncoupling a few elements, or diminishing the anode-surface, or finally by suspending more objects in the bath.

The density of current most suitable for nickelling copper, copper-alloys, iron, and steel varies between 0.4 and 0.8 ampère per 15.5 square inches, while zinc, after previous coppering, requires 1.3 to 1.5 ampères.

It is in all respects advisable first to cover the objects by means of a strong current, *i. e.*, to give the first deposit rapidly, in order to withdraw the metals from the action of the bath, and then finish the operation after reducing the current to a suitable strength. With a current thus regulated the objects may be allowed to remain in the bath for hours and even for days. It is further possible to nickel by weight and attain deposits of considerable thickness.

If very thick deposits of nickel are desired, the objects must be frequently turned in the bath, as the lower portions nickel stronger than the upper; further, as soon as the deposit acquires a dull bluish lustre it has to be thoroughly scratch-brushed, in doing which, however, the objects must not be allowed to become dry. After scratch-brushing it is advisable to cleanse the deposit once more with the lime-brush, and after rinsing replace the objects in the bath. If burnt places cannot be brightened and smoothed with the scratch-brush, the desired end is readily attained with the assistance of emery paper or pumice.

For *solid* nickelling it suffices in most cases to allow the objects to remain in the bath until the dull bluish lustre appears, this being an indication that the deposit has acquired considerable thickness, and will not take a further regular deposit. If such objects are permitted to remain longer in the bath without scratch-brushing, the dull bluish tone soon passes into a dull gray, and all the metal deposited in this form must be polished away in order to obtain a bright lustre.

Whether the deposit of nickel is sufficiently heavy for all ordinary demands is, according to Fontaine, shown by rubbing a nickelled corner or edge of the object rapidly and with energetic pressure upon a piece of planed soft wood until it becomes hot. The nickelling should bear this friction.

If the objects, after having been suspended for some time in the bath, are only partially nickelled, it is very likely due to the defective arrangement of the anodes. This occurs chiefly with

large round objects and with articles having deep depressions (cups, vases, etc.).

For flat objects it is sufficient to suspend them between two rows of anodes; round objects with a large diameter should be quite surrounded with anodes, and be as nearly as possible equidistant from them. This arrangement should especially not be neglected where a heavy and uniform deposit of nickel is to be given to round or half-round surfaces—for instance, large half-round stereotype plates for revolving presses.

While for smooth articles the most suitable distance of the anodes from the objects is $3\frac{3}{4}$ to $5\frac{3}{4}$ inches, for objects with depressions and hollows it must be larger, if it is not preferred to make use of the methods described later on. However, a deposit of a uniform thickness cannot be obtained by this means, because the portions nearer to the anodes will acquire a thicker deposit than the hollows; hence the use of a small hand anode, which is connected by means of a thin flexible wire with the anode-rod, and introduced into the depressions and hollows, is to be preferred. This, of course, renders it necessary for a workman to stand alongside the bath and execute the operation by hand; but as the small anode can be brought within a few millimetres of the surface of the article, and at this distance slowly moved around it, a correspondingly thick deposit is in a short time formed.

In nickelling lamp-feet of cast-zinc this operation can hardly be avoided, especially if the depressed portions are also to have a uniformly good deposit.

Besides the above-mentioned rules for nickelling, which also hold good for other electro-plating processes, the following may be given :—

In suspending the objects in the bath rub the metallic hooks or wires, with which they are secured to the rods, a few times to and fro upon the rod, in order to be sure that the place of contact is purely metallic. It is also well to acquire the habit of striking the rod a gentle blow with the finger every time when suspending an object, the gas-bubbles settling on the articles becoming thereby detached and rising to the surface. It is further advisable, before securing the object to the object-rod, several times to move them

up and down; so to say, shake them beneath the fluid, whereby, on the one hand, the layers poorer in metal are mixed with those richer in metal, and, on the other, any dust which may float upon the bath and settle on the objects is removed.

The objects suspended in the bath should not touch one another, nor one surface cover another, and thus withdraw it from the direct action of the anode. In the first case stains will readily form on the places of contact, and in the latter the covered surface acquires only a slight deposit. That the objects must not touch the anodes need scarcely be mentioned.

Objects with depressions and hollows should be suspended in the bath so that the air in the hollows can escape, which is effected by turning the depressions upward, or, if there are several depressions on opposite sides, by turning the articles about after being introduced into the bath. Air-bubbles remaining in the hollows prevent contact with the solution, no deposit being formed on such places.

It remains to say a few words in regard to the so-called polarizing phenomena. In the theoretical part, it has been shown that by dipping two plates of different metals in a fluid a *counter* or *polarizing current* is generated, which is the stronger the further the two metals are removed from one another in the series of electromotive force, and the more they differ in their electrical behavior. If the anodes in a nickel bath are of nickel and the articles of copper, the counter-current will be slight, because copper and nickel stand together in the series of electro-motive force (p. 14). The counter-current, however, becomes greater when iron objects are hung in the bath, and greatest with zinc surfaces which are to be nickelled, because zinc, being the most electro-positive metal, differs widely in its behavior from nickel. Now, since the counter-current flows in a direction opposite to that of the current introduced in the bath, the latter is weakened, and the more so the stronger the counter-current is. This explains why iron requires a stronger current for nickelling than copper alloys, and zinc a stronger one than iron.

Now it may happen that the counter-current becomes so strong as to entirely annul the effect of the principal current, and even to reverse the latter, the consequence being that, in the first case,

the formation of the deposit is interrupted, and, in the latter, that the deposit is again destroyed, and the metals of which the articles consist dissolve and contaminate and spoil the bath. To avoid this, a main current must be conducted into the bath, which, by its sufficiently large electro-motive force, can overcome the counter-current, and the consequences of the reversion of the current can be prevented by using the galvanometer and observing the deflection of its needle, which (according to p. 86) in proper time indicates the appearance of a reversed current. Now if a nickel-plater has only a slight current at his disposal, it follows from the above explanation that before nickelling the more electro-positive metals, such as iron, tin, zinc, it is best to first copper them, and thereby annul the action of these metallic surfaces as regards the formation of the counter-current.

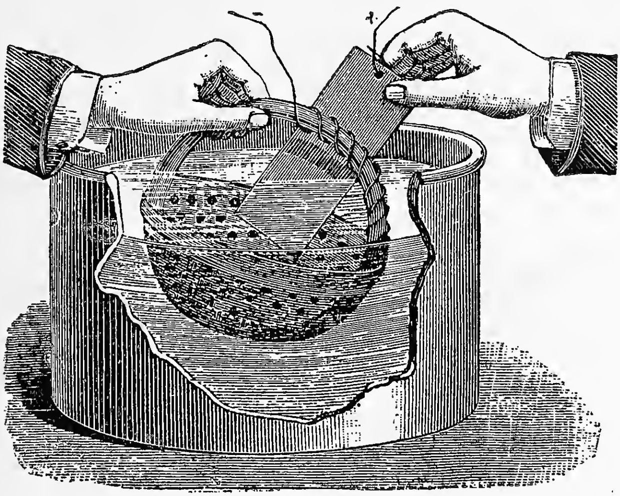
It happens comparatively seldom that the counter-current becomes so strong as to destroy the deposits formed, because for nickelling powerful Bunsen elements, with two acids or dynamo-electric machines with at least 4 volts' tension, are generally used; it is, however, well to acquaint the operator with all possible contingencies, and to explain the reason why the articles are preferably covered with a strong current. Sprague recommends an initial current of 5 volts' tension, but in most cases one of 3.5 volts suffices for nickelling iron and copper alloys.

Nickelling en masse of small and cheap objects.—This is effected by stringing the objects, if feasible, upon a copper wire, and placing a large glass bead between every two objects to prevent the surfaces from sticking together in the bath. Such objects being generally only slightly nickelled, it suffices to allow them to remain for a few minutes only in the bath with a strong current, it being advisable to diligently shake the bundles in order to effect a change of position of the objects and prevent their touching one another, notwithstanding the glass bead placed between them.

Very small objects which cannot be strung upon wire are nickelled in sieves. To the bottom of a stoneware sieve is secured a copper or brass wire, which is connected with the object-rod, and then the objects are placed in the sieve. Since nickel baths, as a rule, do not conduct sufficiently well to nickel the objects in

the sieve, which must be constantly shaken, it is advisable to hold with one hand an anode connected by a flexible wire with the anode-rod in the sieve, while the other holds the sieve (Fig. 100) and constantly shakes and turns it. For nickelling in sieves, it is further advisable to heat the nickel bath.

Fig. 100.



Warren has recently described a solution of nickel and one of cobalt which can be decomposed in a simple cell apparatus. With the nickel solution, which was prepared by dissolving 100 parts by weight of nickel chloride in as little water as possible and mixing with a concentrated solution of 500 parts of Rochelle salt, no satisfactory results could be obtained ; the cobalt solution however yielded good results, and would seem to be suitable for electro-plating small objects *en masse.* It will be further discussed under "Cobalting."

Stripping nickelled articles.—Defective or old nickelling has first to be removed before the objects can be re-nickelled, since nickel will not adhere to a coating of the same metal. Only in a few isolated cases can stripping be effected by grinding the article. The following process, which is applicable to all metals, but especially to iron, may be recommended. It is based on the

property of concentrated nitric acid to dissolve nickel, but not iron. The surface of the latter is changed by the nitric acid in such a manner as to protect it from the further action of the acid, a thin film of magnetic oxide of iron being formed. Iron in this state is designated *passive.* The articles to be treated are first freed from adhering fat by washing in a soap bath or in a solution of caustic soda, or by means of benzine. The rust is next removed, which is best effected by connecting the article with a piece of sheet-zinc and placing it in a mixture of 100 parts water and 1 part sulphuric acid until the rust spots have disappeared, or can at least be readily removed by wiping. The article is then dried and treated in the nitric acid bath. For the latter it is best to use a mixture of 1 part by volume of nitric acid and 10 parts by volume of sulphuric acid of 66° B. The acid mixture should be kept in a vessel of glass, porcelain, or stoneware, or in a wooden trough lined with lead, and when not in use should be covered. The articles to be stripped are placed in the acid bath and allowed to remain until the nickelling is completely dissolved. Should this not be the case in the course of one hour, the articles are taken from the bath by means of an iron tool, rinsed quickly in running water to dissolve and remove the nickel salts not soluble in the acid, and dried with cloths. They are then replaced in the acid. When the nickelling is entirely dissolved, the articles are rinsed in water and brought immediately into the nickel bath, or if they are to be coppered before nickelling, as is frequently done, into a cyanide of copper bath. Iron and steel treated with the above-described acid mixture show, in the passive state, no tendency to the formation of rust, and it might, therefore, be advisable in all cases to pickle articles of iron and steel, which are to be nickelled, in a mixture of nitric and sulphuric acids, after freeing them from fat, in order to counteract the rust spots which frequently show themselves later on, especially in cast-iron. The durability of the nickelling seems not to be affected by the layer of magnetic oxide of iron. Should its removal, however, be deemed desirable, it can be readily effected by connecting the article with a piece of sheet zinc and immersing it in dilute sulphuric acid. Articles of copper, brass, or zinc may also be stripped by immersing them in

the above-mentioned acid bath. After being placed in the stripping bath they should be carefully watched, being frequently taken from the bath to see how the operation progresses, and they should not be allowed to remain in the liquid one moment after the nickel has been dissolved from the surface. The operation of stripping should be conducted in the open air, or in a fireplace with good draught, so that the acid fumes may escape through the chimney. When the stripping of brass or copper work has been properly conducted, the surface of the stripped object presents a smooth and bright surface but little affected by the acid bath.

The old nickelling is removed mechanically by brushing with emery. From depressions as much as possible is removed with the brush, after which the object is freed from grease and pickled and coppered before nickelling. In this case the layer of copper serves as a cement for the old and new deposit, and there will be no danger of the new deposit peeling off in polishing.

It has also been proposed to remove the nickel from the articles by means of the battery or dynamo-machine by making them the anodes in a nickel bath; but in this case a separate solution should be employed for the purpose.

As a remedy against the yellowish tone of the nickelling, Pfanhauser recommends suspending the nickelled articles, immediately after taking them from the nickel bath, as anodes in a nickel bath acidulated with citric or hydrochloric acid, a piece of sheet nickel serving as the cathode, and to allow the current to act for a few seconds. It is claimed that thereby the basic nickel salts separated together with the nickel, and to which, according to Pfanhauser, the yellowish tinge is due, are dissolved and the nickelling will show a pure white tone.

The following is a brief compilation of the principal phenomena which may occur in nickelling, as well as the means of avoiding them: 1. The articles do not become coated with nickel, but acquire discolored, generally darker tones. *Reasons:* The current is either too feeble to effect the reduction of nickel, and the coloration is in consequence of the chemical action of the nickel solution upon the metals constituting the objects. *Remedy:* Increase the current or diminish the area of suspended

objects; also examine whether the current actually passes into the bath, otherwise clean the places of contact.

2. A deposition of nickel takes place, but it is dark or spotted or marbled, even with a sufficiently strong current. *Reasons*: The bath is either alkaline, which has to be ascertained by litmus-paper, and, if so, the slightly acid reaction of the bath has to be restored by the addition of a suitable acid; *or*, the bath is too concentrated, in which case a separation of crystals will be observed. This is remedied by diluting with water; *or*, the nickel solution is very poor in metal, which can be remedied by the addition of nickel salt; it should also be tested as to the admixture of copper, the production of dark tones being frequently due to this. In this case the bath is allowed to work for some time, and if the content of copper is inconsiderable a white deposit will soon be obtained; *or*, the cleaning and pickling of the articles have not been thoroughly done, which is remedied by again cleaning them; *or*, the conducting power of the bath is insufficient, which is remedied by the addition of a suitable conducting salt.

When freshly prepared baths yield dark nickelling, it can generally be remedied by working the bath two or three hours.

3. A yellowish tinge of the nickelling. *Reasons:* See under 2; *or*, with cast-iron an insufficient metallic surface, which is remedied by repeating the scratch-brushing; *or*, unsuitable composition of the bath.

4. The objects rapidly acquire a white deposit of nickel, but the color soon changes to dull gray-black, especially on the lower edges and corners. *Reason:* Too strong a current. *Remedies:* Regulating the current, or hanging in more objects, or uncoupling elements. Frequent turning of the articles.

5. The nickelling is white, but readily peels off by scratching with the finger-nail or by the action of the polishing wheel. *Reasons:* The current is too strong, which is remedied as under 4; *or*, the bath is too acid. This is remedied by the addition of spirit of sal ammoniac, potassium carbonate, or nickel carbonate, according to the composition of the bath: *or*, insufficient cleaning and pickling, which is remedied by thorough cleaning after removing the defective deposit, or, if it cannot be entirely removed, coppering.

6. Though nickelling may proceed in a regular manner, some places remain free from deposit. *Reasons:* Either the surfaces of some of the objects touch one another, or air bubbles are inclosed in cavities ; *or*, faulty arrangement of the anodes. *Remedy:* Removal of the causes.

7. The deposit appears with small holes. *Reason:* A deposit of particles of dust upon the objects. *Remedy:* Remove the dust from the surface. When there is a general turbidity of the bath in consequence of alkalinity, add the most suitable acid, and boil and filter the bath ; *or*, insufficient removal of gas bubbles from the objects. *Remedy:* Shake the object-rods by blows with the finger.

8. Deposition takes place promptly upon the portions of the objects next to the anodes, while deeper portions remain free from nickel or become black ; or the portions covered by the suspending wire show dark lines. *Reason:* Insufficient conducting power of the bath. With large depressions this cannot be remedied by the addition of a suitable conducting salt, but requires treatment with the hand-anode.

Refreshing nickel baths.—According to their composition, the amount of work performed, and the anodes used, the baths will in a shorter or longer time require certain additions in order to keep their action constant. By "refreshing" is not understood the small addition of acid or alkali from time to time required for restoring the original reaction of the baths, but additions intended to increase the metallic content and diminished conductivity.

The metallic content is increased by boiling the bath with some of the nickel salt used in its preparation, while the conductivity is improved by adding, at the same time, so much conducting salt as is necessary to restore the electro-motive force originally required. Nothing definite can, of course, be said in regard to the quantity of such additions, it being advisable to observe their effect on a small portion of the bath, so as to be sure not to spoil the entire bath.

Nickel baths bear, as a rule, refreshing several times, but as in the course of time they take up impurities, even when the greatest care is exercised, it is best to refresh them at the utmost twice, and then to renew them entirely.

Nickel deposits are polished upon felt disks or bobs of cloth, muslin, or flannel, with the use of Vienna lime, rouge, etc. (See "Polishing," page 116.) Sharp edges, corners, and raised portions should be held only with slight pressure against the polishing wheels, they being more strongly attacked by them than flat surfaces. Knife-blades and surgical instruments with sharp edges require special care in polishing, which will be referred to later on.

After polishing, the nickelled objects, especially those with depressions, have to be freed from polishing dirt by brushing with hot soap-water or hot caustic lye, then rinsed in hot water and dried in clean, fine sawdust.

Objects which are not required to be polished, but left *dead*, that is, just as they come out of the nickel bath, should be taken from the bath one at a time, and at once plunged into perfectly clean hot water for a few moments, and then placed aside to dry spontaneously. Dead nickel being very readily stained or soiled, even when touched with clean hands, the work should be handled as little as possible.

Nickelling sheet zinc.—The nickelling of sheet zinc has been surrounded with a great deal of mystery by those engaged in its manufacture, which may, perhaps, be excusable on the ground that there is scarcely another branch of the electro-plating industry in which experience had to be acquired at the sacrifice of so much money and time as in this. Nevertheless the nickelling of sheet zinc makes no greater demand on the intelligence of the operator than any other electro-plating process, it requiring only an accurate consideration of the relations of the electric behavior of zinc towards nickel; consequently, a knowledge of the strength of the counter-current and of the chemical behavior of zinc towards the nickel solution, which may readily dissolve the zinc; further, a correct estimation of the current-intensity required for a determined zinc surface, as well as of the proper anode-surface, and the most suitable composition and treatment of the nickel baths.

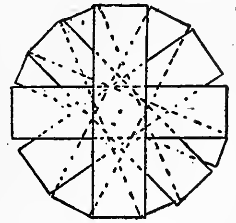
With due observation of these relations, the nickelling of sheet zinc is accomplished as readily as that of other metals; and the proposals to first cover the sheets in a bath with a strong current, and finish nickelling with a weaker current, or to amalgamate the zinc before nickelling, need not be considered.

Below the conditions required for nickelling sheet zinc, and the execution of the process itself, together with the preliminary and final polishing of the sheets, will be fully described.

The preliminary grinding or polishing is effected upon broad cloth disks (buffs) formed of separate pieces of cloth. The polishing lathes run with their points in movable bearings secured in a hanging cast-iron frame by a set screw and safety keys, or preferably as shown in Fig. 86, p. 118, since with this construction an injury to the grinder by the lathe jumping out is impossible.

The buffs, when new, have on an average a diameter of 12 to 16 inches, and a width of $5\frac{3}{4}$ to 8 inches; the principal point in the construction of these bobs is uniform weight on all sides, the quiet running and the possibility of a good polish without great exertion depending on this. Bobs not well balanced run unsteadily and jump, thereby producing fine scratches upon the sheet. The bobs are constructed as follows: A square piece of cloth is folded fourfold and the closed point cut off with a pair of scissors, so that on unfolding the cloth the hole produced by the cut is exactly in the centre of the cloth disk; according to the diameter of the spindle more or less is cut away, but in every case just sufficient that the piece of cloth can be conveniently pushed upon the spindle. The latter, which is provided with a pulley and a hoop against which the pieces of cloth fix themselves, as well as with a nut and screw for securing them, is vertically fastened in a vise, and the separate pieces of cloth are pushed upon it so that the second piece placed in position forms an angle of about 30° (Fig. 101) with the first, the operation being thus continued until the bob has the desired width. Next a small, but very strong iron disk is laid upon the cloth disk, and the separate pieces are pressed together as firmly as possible with the screw. The spindle is then placed in the bearings, and after adjusting the belt upon the pulley the bob is revolved, a sharp knife being held against it to remove the projecting corners. In polishing sheet zinc the bobs make 2400 to 3000 revolutions per minute, according to whether finely rolled or rougher sheets are to be polished.

Fig. 101.



For the purpose of polishing or grinding, the operator places the sheet upon a support of hard wood of the same size and form as the sheet, and grasps the two corners of the sheet nearest to his body, together with the support, with the hands, applying with the balls of the hands the necessary pressure to hold the sheet upon the support. The lower half of the sheet, that furthest from the body, rests upon the knees of the operator, and with them he presses the sheet against the polishing disk, constantly moving at the same time, and at not too slow a rate, the knees from the right to the left, then from the left to the right, and so on. Previous to polishing a streak of oil about 2 inches wide is applied by means of a brush to the centre of the sheet in the visual line of the operator, and the revolving bob is impregnated with Vienna lime by holding a large piece of it against it, when polishing of the lower portion of the sheet begins. When about $\frac{3}{5}$ of the surface has thus been polished, the sheet is turned round and the remaining portion subjected to the same process. The sheet is then closely inspected to see whether there are still dirty or dull places, and, if such be the case, it is polished once more after moistening it with some oil and again impregnating the bob with Vienna lime. The sheet being sufficiently polished, the oil and polishing dirt are removed by dry polishing, after providing the bob with sufficient Vienna lime, so that the sheets when finished show no streaks of dirt or oil.

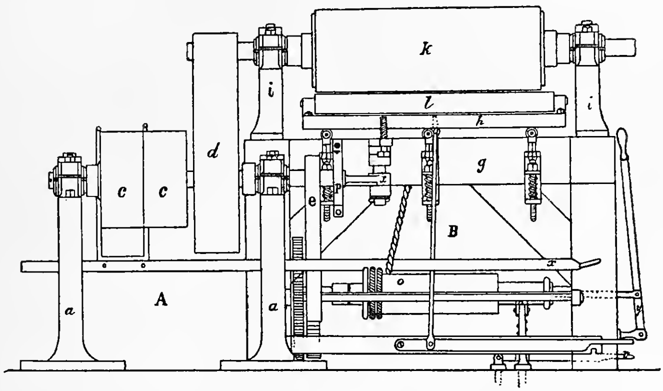
Self-acting sheet polishing machines have been constructed by Dr. Sackur, F. Räuber, Eliachoff, and others. Such machines give a very good polish, but have the disadvantage that thin sheets when polished upon them become wrinkled or wind up on the polishing roller.

In order to explain the principle upon which these machines are constructed, a description of F. Räuber's sheet grinding and polishing machine is given. With this machine metallic sheets of any length can be polished; by the simultaneous lateral and longitudinal motion of the sheet a faultless polish is obtained, streaks and scratches being especially avoided.

The machine essentially consists of the gearing *A* and the actual polishing machine *B*, Figs. 102, 103, 104. The gearing *A* consists of the two standards *a a*, the shaft *b*, a fast and loose

pulley, *c c*, the large driving-wheel *d*, a small-driving wheel, *e*, and the eccentric *f*.

Fig. 102.



The polishing machine *B* consists of the wooden frame *g* with wooden plate *h*, the two standards *i i*, the polishing roller *k*, the iron counter-roller *l*, the expanding contrivance *m*, which is effected by means of three spiral springs, the gearing *n* with the rope-drum *o*, the rope with the tongs *g*, and the shaking arrangement *x*.

The machine is set in motion by the engaging coupling *x* on the gearing *A*. The shaft of the gearing makes about 200 revolutions per minute, and the polishing roller *k* is revolved by a belt from the driving-wheel *d*. At the same time the gearing *n* is set in motion by a belt from the driving-wheel *e*, in consequence of which the rope is wound upon the drum *o*, and the tongs on the rope draw the sheet to be polished under the polishing roller. If the sheet is to go back, the rope-drum *o* is disengaged by means of the coupling *y*, and the polishing roller *k*, which moves lightly upon the counter-roller *l*, draws the sheet back. To prevent the sheet from jumping back, the brake *r* is provided on the rope-drum *o*. By the treadle r_1 the workman is enabled to transport the sheet slowly or rapidly, as may be required. To move the sheet forward, the rope-drum *o* is again engaged. The lateral motion of the sheet is effected by the shaking contrivance *x*.

From the eccentric *f*, of the gearing *A*, the slide rod *t* is con-

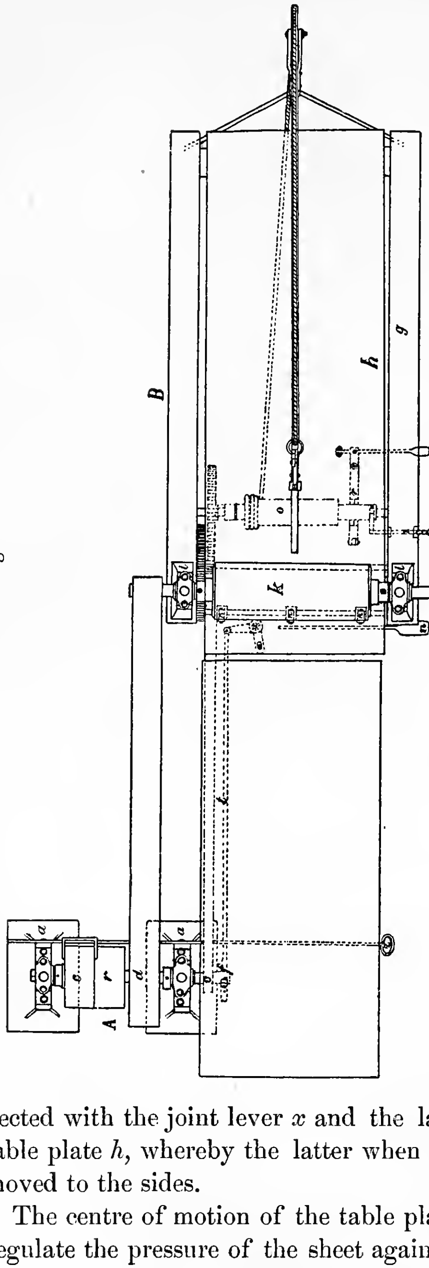


Fig. 103.

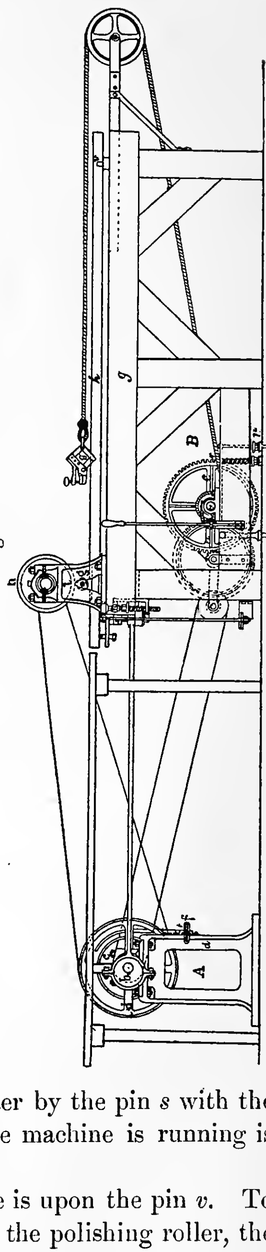


Fig. 104.

nected with the joint lever x and the latter by the pin s with the table plate h, whereby the latter when the machine is running is moved to the sides.

The centre of motion of the table plate is upon the pin v. To regulate the pressure of the sheet against the polishing roller, the

expanding arrangement *m* is placed under the table plate *h*. It consists of three vertical bolts with spiral springs, each of which can be screwed up and down by a nut.

To facilitate the lateral motion of the table plate *h*, the bolts of the expanding contrivance *m* are provided with rolls which press against the plate. If the tension is sufficient and a sheet is to be introduced, it is only necessary to draw the table plate down by means of the treadle *w*, to push the sheet under the polishing roll *k*, and to engage the tongs *g*. In front of the gearing *A* is a table for the reception of the sheet, as shown in the illustration.

The sheets are best freed from grease in two operations, first dry and then wet. For the dry process use a very soft piece of cloth, and, after dipping it in Vienna lime very finely pulverized and passed through a hair sieve, rub over the sheet in the direction at a right angle to the polishing streaks, applying a very gentle pressure. For the wet process dip a wet piece of cloth or a soft sponge free from sand into a paste of impalpable Vienna lime, whiting, and water, and go carefully over the sheet so that no place remains untouched. Then rinse the sheet under a powerful jet of water, best under a rose, being especially careful to remove all the lime, going over the sheet, if necessary, with a soft wet rag and observing whether all portions appear evenly moistened. If such be the case, the cleaning is complete, otherwise the sheet has to be treated once more with lime.

If the sheets are to be nickelled on only one side, two of them are placed together with their unpolished sides and fastened on the two upper corners with binding screws to which is soldered a copper strip about 0.39 inch wide, by which they are suspended to the conducting rods. Plating is then at once proceeded with without allowing the sheets to remain exposed to the air longer than is absolutely necessary. Special care must be had that the lime does not dry, as this would produce stains.

Some manufacturers nickel the cleansed sheets without previous coppering or brassing, and claim special advantages for such direct nickelling. This may be done with a bath of nickel sulphate and potassium citrate without or with a greater or smaller addition of sal ammoniac, according to the area to be nickelled and the intensity of current at disposal. However, sheet zinc directly nickelled

does not shows the warm full tone of sheets previously coppered or brassed; besides, direct nickelling requires a far more powerful current, so that it is not even more economical.

For the nickelling process itself, it is indifferent whether the sheets are previously coppered or brassed, but the choice between the two is controlled by a few phenomena which must be mentioned. The nickel deposit upon brassed sheets shows a decidedly whiter tone than that upon coppered sheets, and brassing would deserve the preference if this process did not require extraordinarily great care in the proper treatment of the bath, the nickel deposit readily peeling off generally in the bath itself, which seldom or never occurs with coppered sheet, and then may generally be considered due to insufficient cleaning or other defective manipulation.

This peeling off of the nickel deposit may be prevented by giving due consideration to the conditions, and avoiding, on the one hand, too large an excess of potassium cyanide in the brass bath, and, on the other, by regulating the current so that no pale yellow or greenish brass is precipitated. Since nickelling with a strong current requires only a few minutes for a deposit of sufficient thickness capable of bearing polishing, it is generally desired to brass the sheets at the same time, so that the operation may proceed rapidly and continuously. To do this, a very powerful current has to be conducted into the brass bath, the result being that a deposit with a larger content of zinc and a correspondingly lighter color is formed, but also with a coarser, less adherent structure, and this is the principal reason why the nickel deposit, together with the brass deposit, peels off. To avoid this, the brassing must be done with a current so regulated that the deposit separates uniformly, adheres firmly, and is not porous, the correct progress of the operation being recognized by the color being more like tombac, and not pale yellow or greenish. Where brassing has to be done quickly the content of copper in the brass bath must be increased to such an extent that a powerful current produces a deposit of the above-mentioned color, and, hence, too large an excess of potassium cyanide must be strictly avoided.

It will be seen that the brassing requires a certain attention

which is not necessary in coppering, and therefore the latter is to be preferred.

For coppering, one of the baths, III. or V., given under "Coppering" serves, to which, for this special purpose, more potassium cyanide may be added. The sheets should remain in this bath no longer than required to uniformly coat them with a beautiful red layer of copper, and under no circumstances must they be allowed to remain until the coppering commences to become dull or even discolored; and they should come from the bath with a full or at least half lustre. When taken from the copper bath the sheets are thoroughly rinsed in a large water reservoir, the contents of which must be frequently renewed, care being had to remove any copper solution adhering to the unpolished sides which are not to be nickelled, since that would soon spoil the nickel bath. The sheets are then immediately brought into the nickel bath, it being best to suspend two, three, or four plates at the same time, to prevent one from being more thickly nickelled than the other, and take them out the same way. In suspending the plates in the bath care should be had to bring them as soon as possible in contact with the conducting rod, a neglect of this rule being apt to produce blackish streaks and stains.

Every separate nickel bath in which sheets are to be nickelled must be fed with the full current of a dynamo-machine, one of 250 to 300 ampères with 4 volts' tension being generally used. According to the number of sheets, generally 6 to 8, each 20×20 inches, to be nickelled, the dimensions of the vats are as follows: 63 inches long, $15\frac{3}{4}$ inches wide, and $25\frac{1}{2}$ inches deep, *or*, 83 inches long, $15\frac{3}{4}$ inches wide, and $25\frac{1}{2}$ inches deep. One to two minutes suffice to give 6 sheets a sufficiently thick deposit of nickel with a dynamo-machine of the above-mentioned capacity, and 2 to 3 minutes for eight sheets, and it may be accepted as a rule that, with a bath of good conductivity, a density of current of from 1.4 to 1.5 ampères and 5 volts' tension is required per 15.5 square inches of zinc surface for the solid nickelling of the sheets. For nickelling zinc in baths conducting with difficulty, for instance, a simple solution of sulphate of nickel and ammonia without the addition of conducting salts, or in baths containing boric acid, 1.3 to 1.4 ampères and 6 to 7 volts must be allowed

per 15.5 square inches of zinc surface if the nickelling is to be effected in the above-named space of time. A density of current of 1.4 to 1.5 ampères and 4 to $4\frac{1}{2}$ volts, at which the sheets have to remain in the bath for 3 minutes, is the most suitable, the deposit thus obtained being in every respect faultless, provided the nickel bath is of proper composition.

For nickelling sheet zinc rolled anodes are, as a rule, only used, except when working with baths containing boric acid. The anode surface must at least be equal to that of the zinc surface; the distance between the anodes and the sheets should be from 3 to $3\frac{3}{4}$ inches, and when the current-strength is somewhat scant the distance may be reduced to $2\frac{1}{2}$ inches. The nickel anodes have to be taken from the bath once daily and scoured bright with scratch-brushes and sand; for the rest, all the rules given for nickel anodes are valid.

Baths used for nickelling sheet zinc soon become alkaline in consequence of the powerful current used, which is shown by red litmus-paper turning blue; the alkalinity also manifests itself by the bath becoming turbid and the nickelling not turning out a pure white. The slightly acid reaction is restored by citric acid solution. The appearance of the dreaded *black streaks* and *stains* is due either to the current itself being too weak or to its having been weakened by an extremely great resistance of the nickel bath; also to an insufficient metallic surface of the anodes, which may be either too small or not sufficiently metallic on account of tarnishing; and finally to an excessive alkalinity of the bath or insufficient contact of the hooks with the connecting rods.

The metallic content of the bath must from time to time be augmented by the addition of nickel salt, and the bath filtered at certain intervals. When the conductivity abates it has to be be restored by the addition of conducting-salt.

When the sheets have been sufficiently nickelled, they are allowed to drain off, then plunged into hot water, and, after removing the binding-screws, dried by gentle rubbing with fine sawdust free from sand and passed through a fine sieve to separate pieces of wood. In all manipulations, the unnickelled sides are placed together, while a piece of paper of the size and form of the sheets is laid between the nickelled sides.

The nickelled sheets are finally polished, which is effected by placing them upon supports and pressing against the revolving bob as previously described, the sheets being, however, only moderately moistened with oil, and not too much Vienna lime applied to the bob. Polishing is done first in one direction and then in another, at a right angle to this first. After polishing, the sheets are finally cleansed with a piece of soft cloth and impalpable Vienna lime, after which they should show a pure white lustrous nickelling, free from cracks and stains, and bear bending and rebending several times without the nickelled deposit breaking or peeling off.

Nickelling of tin plate.—For elegant and durable nickelling tin plate also requires previous coppering. The deposit is effected with a less powerful current than is used for sheet zinc. Scouring is done as described for sheet zinc, also the polishing of the nickelled tin plate.

The treatment of *copper and brass sheets* differs from that of sheet zinc in that the rough sheets are first brushed with emery and then polished with the bob. After treating the sheets with hot caustic lye or lime-paste, they are pickled by brushing them over with a solution of 1 part of potassium cyanide in 20 of water; they are then thoroughly and quickly rinsed, and immediately brought into the bath. To avoid peeling off, the current must not be too strong.

Nickelling of sheet-iron and sheet-steel.—Only the best quality of sheet should be used for this purpose. After rolling, the sheets are freed from scales by pickling, then passed through the fine rolls, and finally again pickled. If the nickelled sheets are not to exhibit a high degree of polish, it suffices to brush them before nickelling with a large broad fibre brush (p. 115) and emery No. 00. But for a high lustre, such as is generally demanded, the sheets have first to be ground. For fine grinding the pickled sheets broad massive cylinders of poplar wood are used, which are covered with leather and turned like the disks described on p. 112. These cylinders are 10 to 12 inches in diameter, and 2 to 4 or more inches long, according to the size of the sheets. For the first grinding, the cylinders are coated with glue and rolled in emery No. 100 to 120, according to the condition of the sheets,

while emery No. 00 is applied to the cylinders used for fine grinding. The grinding is succeeded by brushing, as described on p. 112.

After preparing a sufficiently smooth surface, the sheets are at once rubbed with a rag moistened with petroleum, or, if preferred, with a rag and pulverized Vienna lime; they are then scoured wet in the manner described for sheet-zinc, p. 173. The scouring material must be liberally applied, especially if the sheets are to be directly nickelled without previous coppering, as is advisable. After rinsing off the lime-paste, the sheets are brushed over with very dilute sulphuric acid (1 part acid to 25 water), rinsed off, then lightly brushed over once more with lime-paste, again carefully rinsed, and immediately brought into the nickel bath.

The current should be neither too strong nor too weak, but regulated so that the nickelling is of sufficient thickness in 15 to 20 minutes without showing a tendency to peel off. It is not advisable to try to obtain a heavy deposit in a shorter time, because it would lack density, which is the principal requirement for nickelled sheet-iron.

After nickelling, the sheets are rinsed in clean water, then plunged into hot water and dried by rubbing with warm sawdust. After this operation, it is recommended to thoroughly dry the sheets in an oven heated to between 176° and 212° F., to expel any moisture from the pores, and then to polish them with Vienna lime and oil or with rouge.

Nickelling of wire.—Nickelling of wire of iron, brass, or copper is scarcely ever done on a large scale; it is, however, believed that the nickelling of iron and steel wires—for instance, piano-strings—might be of advantage to prevent rust or at least to retard the commencement of oxidation as long as possible.

To nickel single wires cut into determined lengths, according to the general rules already given, is simple enough; but this method cannot be pursued with wire several hundred yards long, rolled in coils, as it occurs in commerce. Nickelling the wire in coils, however, cannot be done, as only the upper windings exposed to the anodes would acquire a coat of nickel. Hence it becomes necessary to unwind the coil, and for continuous working pass the

wire at a slow rate through the cleansing and pickling baths, as well as the nickel bath and hot water reservoir, as shown in Fig. 105 in cross-section, and in Fig. 106 in ground plan.

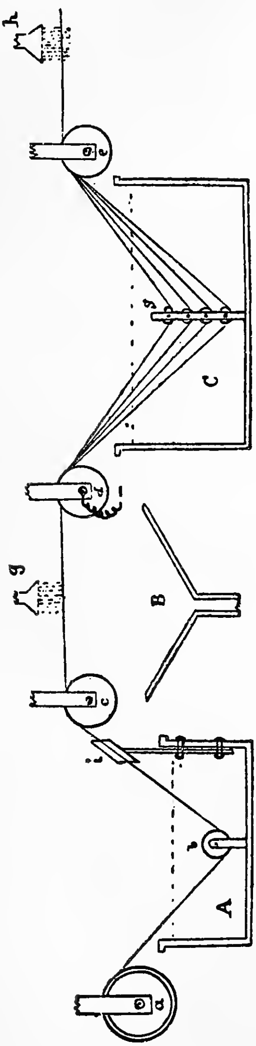


Fig. 105.

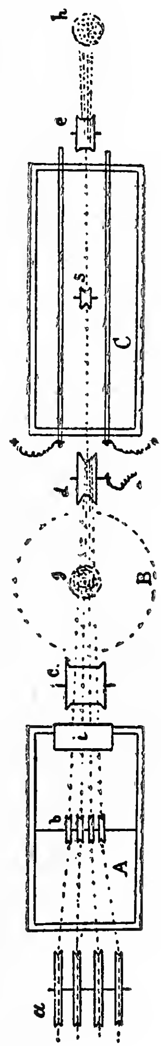


Fig. 106.

The unwinding of the wire is effected by a slowly revolving shaft, upon which the nickelled wire again coils itself; but in the

illustration the shaft is omitted. In Fig. 105 four wires run over the four rolls *a*, mounted upon a common shaft, to the rolls *b* upon the bottom of the vat *A*, whereby they come in contact with a thickly fluid lime-paste in the vat, and are freed from grease. From the rolls *b* the wires run through the wooden cheeks *i*, lined with felt, which retain the excess of lime-paste, and allow it to fall back into the vat. The wires then pass over the roll *c* to the roll *d*. Between these two rolls is the rose *g*, which throws a strong jet of water upon the wires, thereby freeing them from adhering lime-paste. The roll *d*, as well as its axis, is of brass, and to the latter is connected the negative pole of the battery or dynamo, so that by carrying the wires over the roll *d* negative electricity is conducted to them. From the roll *d* the wires run over the roll-bench *s* (Fig. 105) to the vat *C*, which contains the nickel solution, so that they are subjected to the action of the anodes arranged in this vat on both sides of the wires. The wires then pass over the roll *e*, are rinsed under the rose *s*, and run finally through a hot water reservoir and sawdust (these two apparatuses are not shown in the illustration), to be again wound into coils. In case a high polish is required, the nickelled wires may be run under pressure through leather cheeks dusted with Vienna lime.

Nickelling wire-gauze.—Messrs. Louis Lang & Son obtained, in 1881, a patent for a method of nickelling wire gauze, or wire to be woven into gauze, more especially for the purpose of paper manufacture. These wires, which are generally of copper or brass, are liable to be attacked by the small quantities of chlorine which generally remain in the paper pulp, by which the gauze wire eventually suffers injury. To nickel wire before it is woven, it is wound on a bobbin and immersed in a nickel bath, in which it is coated with nickel in the usual way; it is then unwound and re-wound on to another bobbin, and reimmersed in a nickel bath, as before, so as to coat such surfaces as were in contact with each other and with the first bobbin. To deposit nickel on the woven tissue it may either be coated in its entire length, as it leaves the loom, or in detached pieces. For this purpose the wire gauze is first immersed in a pickle bath, and next in the nickel solution. On leaving the latter it is rinsed and then placed in a hot air

chamber, and when thoroughly dry may be rolled up again ready for use.

Nickelling of knife-blades, sharp surgical instruments, etc.—Most electro-platers experience considerable trouble in nickelling sharp-edged instruments, the edges and points being invariably spoiled either by the deposit of nickel or in polishing. The following directions for the convenient nickelling of such instruments without any damage being done to the edges, are given by the *Metal-arbeiter*, and can be recommended: New articles which have not been used require no special preparation, they being at once freed from grease and brought into the bath. But instruments which have been used, and are partly or entirely coated with rust, must first be ground after the removal of the rust by chemical or mechanical means. The marks left by the stone or emery wheel are effaced by means of the circular brush. But in brushing, the edges are rendered dull if special precautionary measures are not used. For instance, the edge of a knife-blade must never come in contact with the brush. This is prevented by firmly pressing the blade flat upon a soft support of felt or cloth, so that the edge sinks somewhat into the support, without, however, cutting into it. The edge is then held downward and thus together with the support brought against the revolving brush. In this manner the blades may be vigorously brushed without fear of spoiling the edges.

The treatment in giving them a high polish after nickelling is the same. Freeing from grease may be done in the usual manner with lime-paste; but must also be effected upon a soft support, the same as in polishing. After thorough rinsing in clean water the separate pieces, *without* being previously coppered, are brought directly into the nickel bath, the composition of which must, of course, be suitable for nickelling steel articles. The instruments are first coated with the use of a strong current, so that the deposition takes place slowly and with great uniformity.

In suspending the articles in the bath, care should be had that neither a point nor an edge is turned towards the anodes. It is best to use a bath with anodes on one side only, and to suspend the blades with their backs towards the anodes. If, for any reason, the instruments are to be suspended between two rows of an-

odes, the edges should be uppermost, as near as possible, to the level of the bath ; but they should never hang deep or downwards.

After nickelling the instruments are polished for high lustre, but must always be exposed upon a soft support, as above described, to the action of a felt disk, or, still better, of a cloth bob.

Nickelling of electrotypes, clichés, etc.—The advantages of nickelling electrotypes, etc., over steeling will be discussed under "Steeling," and hence only the most suitable composition of the nickel baths and the manipulations required will here be discussed.

The nickel baths according to formula III. (page 148) and formula VII. (page 150) are the most suitable for simple nickelling, because the ammonium sulphate not being present in too great an excess, as well as the presence of boric acid, causes the nickel to separate with great hardness. With nickelled electro-plates three times as large an edition can be printed as with plates of the same material not nickelled.

It being a well-known fact that a fused alloy of nickel with cobalt possesses greater hardness than either of the metals by themselves, experiments proved that an electro-deposited nickel-cobalt alloy exhibited the same behavior, the greatest degree of hardness being attained with an addition of cobalt varying between 25 and 30 per cent. For this deposit the term *hard nickelling* is proposed, the most suitable baths for the purpose being prepared according to the following formulæ: I. Nickel-ammonium sulphate 21.16 ounces, cobalt-ammonium sulphate 5.29 ounces, ammonium sulphate 8.8 ounces, water 15 quarts; *or*, II. Nickel-ammonium sulphate 21.16 ounces, cobalt-ammonium sulphate 5.29 ounces, crystallized boric acid 10.58 ounces, water 15 quarts.

Bath No. I. is prepared by simply dissolving the salts in heated water, and, in case the bath is too acid, adding spirits of sal ammoniac until blue litmus-paper is only slightly reddened. It is best to use rolled and cast anodes in equal proportions; and when the bath becomes alkaline to restore its original slightly acid reaction by the addition of citric acid.

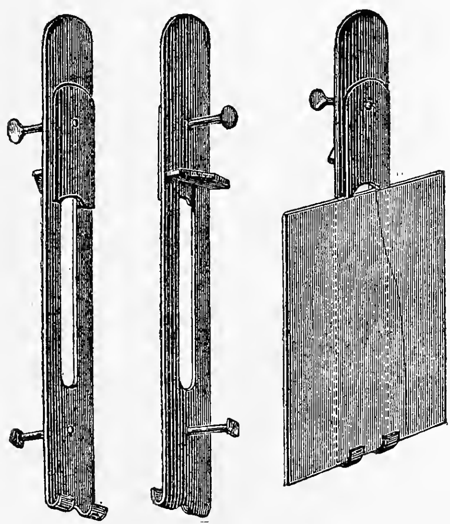
To prepare bath No. II. dissolve the constituents by boiling; and in case not entirely neutral metallic salts have been used, add to the hot solution, with constant stirring, 1 to $1\frac{3}{4}$ ounces of

nickel carbonate for the neutralization of free sulphuric acid which may be present. This bath must not be neutralized, but worked with its strongly acid reaction, mixed anodes being also used.

The bath prepared according to formula No. II. deserves the preference, it yielding a harder deposit than bath No. I.

For the rest, the treatment of the baths is the same as that given for nickel baths of similar composition (pp. 148 and 150), and the process of hard nickelling does not essentially differ from ordinary nickelling. The suspending hooks are soldered to the backs of the plates by means of the soldering-iron and a drop of tin; or the plates are secured in holders of sheet-copper 0.11 inch thick, and $\frac{3}{4}$ to 1 inch wide, of the form shown in Fig. 107. The printing surface is freed from grease by brushing with lime-paste, rinsed in water, and then brushed with a clean brush to remove

Fig. 107.



the lime from the depressions. The plates are then hung in the bath and covered with a strong current. When everywhere coated with nickel the current is weakened and the deposit allowed gradually to augment. With an average duration of nickelling of 15 to 20 minutes, with 2.8 to 3 volts, the deposit will, as a rule, be sufficiently resisting.

The nickelled plates are rinsed in water, then plunged in hot water, and dried in sawdust, when the nickelled printing surface may be brushed over with a brush and fine whiting, it being claimed that plates thus treated take printing-ink better, while the first impressions of plates not brushed with whiting are somewhat dull.

Nickel-facing is especially suitable for copper plates for color-printing, the nickel being not attacked like copper or iron by vermilion.

Recovery of nickel from old baths.—At the present low price of nickel its recovery from old solutions scarcely pays. The uselessness of the bath is in most cases due to two causes: it has either become too poor in metal or it contains foreign metallic admixtures. In the first case, the expense of evaporating with the further manipulation is out of proportion to the value of the nickel recovered; and, in the second case, the reduction of the foreign metals is inconvenient and connected with expenses making it unprofitable.

Urquhart proposes the following plan for recovering nickel from old solutions: Make a saturated solution of ammonium sulphate in warm water, and add to it the old nickel-plating solution with constant stirring, and, after the lapse of a few minutes, a granular precipitate of the double sulphate of nickel and ammonium will begin to separate. The addition of ammonium sulphate should be continued from time to time until the liquid is colorless. The precipitated salt is very pure, and may be used directly in making a new bath.

To improve defective nickelling.—With the basis-metal thoroughly cleansed defective places should not occur, but when they happen by accident or negligence recourse is had to "doctoring." The "doctor" is arranged as follows: A piece of stout copper wire is bent in the form of a hook at each end, and a fragment of nickel anode is fastened firmly to one of the hooks with a piece of twine. The fragment of anode is then wrapped in several folds of muslin, the second hook connected by a wire to the anode-rod of the bath, and the article put in contact with the negative electrode. The rag end is now dipped in the nickel bath, applied to the defective spot, and allowed to rest upon it for a few moments,

then dipped again and reapplied. By repeatedly dipping the rag in the nickel bath and applying it in this way a sufficient coating of nickel may be given in a few minutes, and if the operation is skilfully performed, no trace of the patch will be observable after polishing.

Nickelling by contact and boiling.—Franz Stolba has described a nickelling process by contact, which is executed as follows:—

In a bright copper kettle heat to boiling a concentrated solution of zinc chloride with an equal or double the volume of soft water, and then add drop by drop pure hydrochloric acid until the precipitate formed by diluting the zinc chloride solution with water disappears. Then add as much zinc powder as will lie upon the point of a knife, the effect of this addition being that the copper of the kettle as far as it comes in contact with the solution is in a few minutes zincked. Now bring into the kettle sufficient nickel salt, best nickel sulphate, to color the fluid perceptibly green; then introduce the articles to be nickelled together with small pieces of sheet zinc or zinc wire, so as to present many points of contact, and continue boiling. With a correct execution of the process it is claimed the articles will be uniformly nickelled in 15 minutes; if such is not the case, the boiling must be continued, fresh pieces of zinc added, or, if the solution does not appear sufficiently green, fresh nickel salt introduced.

For the success of the process several conditions are necessary. The metallic articles must be thoroughly free from grease, as otherwise no deposit of nickel is formed on the greasy places. In boiling, the solution must not become turbid by the separation of basic zinc salt, nor acid by free hydrochloric acid, otherwise the nickelling will be dull and blackish. Hence, any turbidity must be at once removed by adding drop by drop hydrochloric acid, and too great acidity by the careful addition of solution of carbonate of soda. The articles thus nickelled are to be thoroughly washed with water, dried, and polished with whiting.

Since stains are readily formed by this process, especially when nickelling polished iron and steel articles, on the places where the metal to be nickelled comes in contact with the zinc, Stolba in later experiments omitted the zinc, and thus the contact process becomes a boiling process. To a 10 per cent. solution of zinc chloride add

enough nickel sulphate to give the solution a deep green color and then heat, best in a porcelain vessel, to the boiling-point. Then without troubling about the turbidity of the bath caused by the separation of a basic zinc salt, immerse the objects, previously cleansed and freed from grease, in it in such a way that they do not touch each other, or at least in only a few places, and keep the whole boiling 30 to 60 minutes, from time to time replacing the water lost by evaporation. The after-treatment is the same as given above for the contact process; the deposit of nickel is, of course, very thin.

This process, while suitable for the amateur, cannot be recommended to the professional electro-plater, the results not being sufficiently sure. A thin deposit of nickel of a light color may be obtained upon brass articles, but that upon iron articles is dark and mostly stained.

Small articles, which are not to be nickelled by the battery, are preferably coated by contact with cobalt by the process to be described later on, under "Electro-cobalting." The higher price of cobalt salts makes little difference, small quantities only being required, and the color of cobalt can scarcely be distinguished from that of nickel.

By boiling a solution of 8½ ozs. of nickel-ammonium sulphate and 8½ ozs. of ammonium chloride in 1 quart of water, together with clean iron filings free from grease, and introducing into the fluid copper or brass articles, the latter become coated with a thin layer of nickel capable of bearing light polishing. The nickel solution has to be frequently renewed.

According to R. Kaiser, an alloy containing nickel may be deposited upon articles by proceeding as follows: Melt 1 part of copper and 5 of tin, and granulate the fused mass by pouring it through a heated sheet-iron sieve into a bucket filled with water. Boil the granulated metal thus obtained with tartar free from lime, and add for every 100 parts by weight of granulated metal 0.5 part of glowed nickel oxide. Then bring the brass or copper articles, previously freed from grease and pickled, into the boiling fluid, and after boiling for a short time they will appear coated with a white alloy resembling German silver. The addition of nickel oxide must be repeated from time to time. Iron and steel

articles are to be previously coppered. By adding nickel carbonate to this bath, it is claimed, coats richer in nickel and of a darker color than that of platinum to blue-black are obtained.

Deposits of nickel alloys.—From suitable solutions of the metallic salts nickel may be deposited together with copper and tin, as well as with copper and zinc. With the first combination, especially, all tones from copper-red to gold shade may be obtained according to which metal predominates, or according to the current-strength which is conducted into the bath, as is also the case in brassing.

A suitable bath for coating metallic articles with an alloy of nickel, copper, and tin, for which the term *nickel-bronze* is proposed, is obtained by dissolving the metallic phosphates in sodium pyrophosphate solution. By mixing solution of blue vitriol with solution of sodium phosphate, cupric phosphate is precipitated, which is filtered off and washed. In the same manner nickel phosphate is prepared from a solution of nickel sulphate. These phosphates are then, each by itself, dissolved in a concentrated solution of sodium pyrophosphate, while chloride of tin is directly dissolved in sodium pyrophosphate until the turbidity, at first rapidly disappearing, disappears but slowly.

Nothing definite can be said in regard to the mixing proportions of these three solutions, because the proportions will have to be varied according to the desired color of the deposit; the operator, however, will soon find out of which solution more must be added in order to obtain the tone desired.

For depositing an alloy of nickel, copper, and zinc, solutions of cupric sulphate (blue vitriol) and zinc white in potassium cyanide, to which is added an ammoniacal solution of nickel carbonate, may be advantageously used.

According to a French process, a deposit of German silver may be obtained as follows: Dissolve a good quality of German silver in nitric acid and add, with constant stirring, solution of potassium cyanide until all the metal is precipitated as cyanide. The precipitate is then filtered off, washed, dissolved in potassium cyanide, and the solution diluted with double the volume of water. This process, however, does not seem very feasible, since nickel separates with difficulty from its cyanide combination.

Watt recommends the following method: Cut up into small pieces sheet German silver about 1 oz., place the strips in a glass flask, and add nitric acid diluted with an equal bulk of water. Assist the solution of the metal by gentle heat. When red fumes cease to appear in the bulb of the flask, decant the liquor and apply fresh acid, diluted as before, to the undissolved metal, taking care to avoid excess; it is best to leave a small quantity of undissolved metal in the flask, by which an excess of acid is readily avoided. The several portions of the metallic solutions are to be mixed and diluted with about 3 pints of cold water in a gallon vessel. Next dissolve about 4 ozs. of carbonate of potash in a pint of water, and add this gradually to the former, with gentle stirring, until no further precipitation takes place. The precipitate must be washed several times with hot water, and then redissolved by adding a strong solution of cyanide, with stirring, and about 1 oz. of liquid ammonia. To avoid adding too great an excess of cyanide, it is a good plan, when the precipitate is nearly all dissolved, to let it rest for half an hour or so, then decant the clear liquor, and dissolve the remainder of the precipitate separately. A small excess of cyanide solution may be added as "free cyanide," and the whole mixed together and made up to one gallon with cold water. The solution should then be filtered or allowed to repose for about 12 hours, and the clear liquor then carefully decanted from any sediment which may be present from cyanide impurities. The bath must be worked with a German-silver anode, which should be of the same quality as that from which the solution is prepared; a Bunsen battery should be employed as the source of electricity, or a dynamo-machine.

2. *Cobalting.*

Properties of cobalt.—Cobalt has nearly the same color as nickel, with a slightly reddish tinge; its specific gravity is 8.56. It is exceedingly hard, highly malleable and ductile, and capable of taking a polish. It is slightly magnetic, and preserves this property even when alloyed with mercury. It is rapidly dissolved by nitric acid and slowly by dilute sulphuric and hydrochloric acids.

For cobalting, the baths given under nickelling may be used by substituting for the nickel salt a corresponding quantity of cobalt salt. By observing the rules given for nickelling, the operation proceeds with ease. Anodes of metallic cobalt are to be used in place of nickel anodes.

Nickel being cheaper and its color somewhat whiter, electro-plating with cobalt is but little practised. On account of the greater solubility of cobalt in dilute sulphuric acid it is, however, under all circumstances, to be preferred for facing valuable *copper plates* for printing.

According to the more or less careful adjustment of such plates in the press, many places of the facing are more or less attacked, and it may be desired to remove the coating and make a fresh deposit. For this purpose, Gaiffe has proposed the use of cobalt in place of nickel, because the former dissolves slowly but completely in dilute sulphuric acid. He recommends a solution of 1 part of chloride of cobalt in 10 of water. The solution is to be neutralized with aqua ammonia, and the plates are to be electro-plated with the use of a moderate current.

Cobalt precipitated from its chloride solution does not however yield a hard coating, and hence the following bath is recommended for the purpose: Double sulphate of cobalt and ammonium 21 ozs., cobaltous carbonate 0.8 oz., crystallized boric acid $10\frac{1}{2}$ ozs., water 10 quarts.

The bath is prepared in the same manner as No. VII., given under "Nickelling." It requires a tension of 2.5 to 2.75 volts.

To determine whether and how much copper is dissolved in stripping the cobalt deposit from cobalted copper plates, a copper plate with a surface of $7\frac{3}{4}$ square inches was coated with 7.71 grains of cobalt and placed in dilute sulphuric acid (1 part acid of 66° Bé, to 12.5 parts of water). After the acid had acted for 16 hours, the cobalt deposit was partially dissolved and had partially collected in lamina upon the bottom of the vessel, the copper plate being entirely freed. On weighing the copper plate it was shown that it had lost about 0.0063 per cent., this loss being apparently chiefly from the back of the plate, the engraved side exhibiting no trace of corrosion. This experiment proved that there is no danger of destroying the copper plate by stripping

the cobalt deposit with dilute sulphuric acid, provided the operation is executed with due care and attention.

Warren has recently described a cobalt solution which can be decomposed in a single cell apparatus, and for this reason would seem suitable for electro-plating small articles *en masse*. For the preparation of this bath dissolve 3½ ounces of chloride of cobalt in as little water as possible, and compound the solution with concentrated solution of Rochelle salt until the voluminous precipitate at first formed is almost entirely redissolved, and then filter. Bring the bath into a vessel and place the latter in a clay cell filled with concentrated solution of sal ammoniac or of common salt and containing a zinc cylinder. Connect the objects to be plated to the zinc by a copper wire and allow them to dip in the cobalt solution. With a closed current the objects become gradually coated with a lustrous cobalt deposit which, after 2 hours, is sufficiently heavy to bear vigorous polishing with the bob. Zinc may be coated in the same manner.

The following solution has been recommended by Mr. G. W. Beardslee, of Brooklyn, N. Y., and is claimed to yield a good deposit of cobalt which is very white, exceedingly hard, and tenaciously adherent: Dissolve pure cobalt in boiling hydrochloric acid and evaporate the solution to dryness. Next dissolve 4 to 6 ozs. of the resulting salt in 1 gallon of distilled water, to which add liquid ammonia until it turns red litmus-paper blue. The solution being thus rendered slightly alkaline is ready for use. A battery power of from two to five Smee cells will be sufficient to do good work. Care must be had not to allow the solution to lose its slightly alkaline condition upon which the whiteness, uniformity of deposit, and its adhesion to the basis-metal greatly depend.

For cobalting small fancy articles of copper, brass, or steel, R. Daub recommends the following bath: Dissolve 4¾ ozs. of double sulphate of cobalt and ammonium in 4½ quarts of water. The solution should show, at 59° F., a specific gravity of 1.015. The most suitable current-strength is 0.8 ampère with about two volts. The size of the anodes is of great influence as regards the uniformity of the cobalting. For the deposition of cobalt upon brass, copper, steel, or iron, the anodes may consist of rolled cobalt in strips

about 2 inches wide and 10 to 12 inches long, according to the size of the articles. The anodes are arranged on the sides of the vat, about 6 inches apart. With the use of a large vat—holding from 500 to 1000 quarts of bath—a corresponding series of such anodes are to be suspended to a conducting rod which rests lengthwise upon the ends of the vat. The metallic articles should be coated with a thin film of cobalt in a few seconds after having been suspended in the bath, and the current-strength is then reduced, to be increased only when more articles are brought into the bath. The mode of treatment is different from that in the nickel bath, and, since cobalt deposits with greater ease than nickel, the regulation of the current is the principal point. The current-strength should be reduced as soon as the articles are entirely and nicely coated with cobalt. Copper articles require at the beginning a stronger current than brass objects, while for articles of iron or steel the current should be weaker than for either brass or copper. Places in relief should be kept as far as possible from the anodes to prevent blackening or burning. According to R. Daub, the principal condition for the success of the operation is to maintain a uniform density of the bath, either by the addition of water or of cobalt salt, as may be required. The color of the deposit is much influenced by the current-strength. Thus a deposit with 1 volt and a large anode-surface is not so white as one with 2 volts and a smaller anode-surface, about $\frac{2}{3}$ of that of the cathode. Cast-brass is especially suitable for cobalting, as well as metallic articles which are kept in dry rooms or used for ornamental purposes.

Cobalting by contact.—While nickelling by contact with zinc yields only incomplete results, the cobalting of copper and brass articles succeeds very well with the use of the following bath: Crystallized cobalt sulphate 0.35 oz., crystallized sal ammoniac 0.07 oz., water 1 quart. Heat the bath to between 104° and 122° F., and immerse the previously cleansed and pickled articles in the bath, bringing them in contact with a bright zinc surface not too small; for small articles a zinc sieve may be used. In 3 or 4 minutes the coating is heavy enough to bear vigorous polishing.

CHAPTER VIII.

DEPOSITION OF COPPER, BRASS, AND BRONZE.

1. *Coppering.*

Properties of copper.—Copper has a characteristic red color, and possesses strong lustre; it is very tenacious, may be rolled to thin lamina, and readily drawn into fine wire. The specific gravity of wrought copper is 8.95, and of cast 8.92. Copper fuses more readily than gold, but with greater difficulty than silver.

In a humid atmosphere containing carbonic acid, copper becomes gradually coated with a green deposit of basic carbonate; when slightly heated it acquires a red coating of cuprous oxide, and when strongly heated a black coating of cupric oxide with some cuprous oxide. Copper is most readily attacked by nitric acid, but is slowly dissolved when immersed in heated hydrochloric or sulphuric acid; with exclusion of the air, it is not dissolved by dilute sulphuric or hydrochloric acid, and but slightly with admission of the air. Liquid ammonia causes a rapid oxidation of copper in the air and the formation of a blue solution. An excess of potassium cyanide dissolves copper. Sulphuretted hydrogen blackens bright copper.

Copper baths.—The composition of these baths depends on the purpose they are to serve, and below are mentioned the most approved baths, with the exception of the acid copper bath used for plastic deposits of copper, which will be discussed later on under "Copper galvanoplasty."

In most cases the more electro-positive metals, zinc, iron, tin, etc., are to be coppered either as preparation for the succeeding process of nickelling, silvering, or gilding, or to protect them against oxidation, or for the purpose of decoration. The above-mentioned electro-positive metals, however, decompose acid copper solutions and separate from them pulverulent copper, while an equivalent portion of zinc, iron, tin, etc., is dissolved. For this

reason, such solutions of copper cannot be used for coating these metals for this purpose, alkaline copper baths being exclusively employed, which may be arranged under two groups—those containing potassium cyanide, and those without it.

Hassauer prepares a copper bath by dissolving $3\frac{1}{2}$ ozs. of copper cyanide in a solution of $17\frac{1}{2}$ ozs. of 70 per cent. potassium cyanide in 3 quarts of water, boiling, filtering, and diluting with 7 quarts of water to a 10 quart bath. This bath works very well when heated to between 113° and 122° F., but when used cold requires a very strong current, and hence the use of the following formulæ is recommended :—

Copper baths for iron and steel articles.—I. *To be used at the ordinary temperature.*—Water 10 quarts, crystallized bisulphite of soda 7 ozs., carbonate of soda 14 ozs., neutral acetate of copper 7 ozs., 75 per cent. potassium cyanide 7 ozs., spirits of sal ammoniac 4.4 ozs.

II. *To be used at between* 140° *and* 158° *F.*—Water 10 quarts, crystallized bisulphite of soda $2\frac{3}{4}$ ozs., crystallized carbonate of soda 7 ozs., neutral acetate of copper 7 ozs., 75 per cent. cyanide of potassium $9\frac{3}{4}$ ozs., spirit of sal ammoniac 4 ozs.

The baths are best prepared as follows : Dissolve the bisulphite and carbonate of soda in one-half the water, the potassium cyanide in the other half, and mix the copper salt with the spirit of sal ammoniac; then pour the blue ammoniacal copper solution into the solution of the soda salts, and finally add the potassium cyanide solution ; the bath will then be clear and colorless. Boiling, though not absolutely necessary, is of advantage, after which the solution is to be filtered.

The above formulæ are given by Roseleur. However, according to investigations made, the excess of carbonate of soda in formula I. serves no special purpose, but on the contrary, in many cases, is directly detrimental ; neither is the use of ammonia of any special advantage, and it may just as well, or rather better, be omitted. Further, the use of separate baths for cold and warm coppering is at least questionable. It is believed that a single bath suffices for both cases, heating having been found of special advantage only for rapid and thick coppering, or for obtaining

13

particular shades which are produced with difficulty in the cold bath, but without trouble in the heated bath.

The following formula may be highly recommended, a copper bath composed according to it always yielding good and sure results:—

III. Water 10 quarts, crystallized carbonate of soda $8\frac{1}{2}$ ozs., crystallized bisulphite of soda 7 ozs., neutral acetate of copper 7 ozs., 98 or 99 per cent. potassium cyanide $8\frac{1}{2}$ ozs.

The bath is prepared as follows: Dissolve in 7 quarts of warm water the carbonate of soda, *gradually* add the bisulphite of soda to prevent violent effervescence, and then add, with vigorous stirring, the acetate of copper in small portions. Dissolve the potassium cyanide in 3 quarts of cold water, and mix both solutions when the first is cold. By thorough stirring with a clean wooden stick, a clear solution is obtained, which is best boiled for half an hour and then filtered. This bath does not require a strong current, and yields an especially heavy coppering of a beautiful red color; a current of 0.4 ampère at a tension of 3 to 3.5 volts is calculated for $15\frac{1}{2}$ square inches of surface of objects.

Annealed sheets of pure copper with as large a surface as possible serve as anodes. In all baths containing cyanide the anodes become, in a comparatively short time, coated with a greenish slime consisting of a basic copper cyanide mostly soluble in excess of potassium cyanide. When a very thick formation of such slime takes place, potassium cyanide is wanting, and has to be added. Other phenomena appearing in copper baths containing cyanide may as well here be mentioned. Too large an excess of potassium cyanide causes a strong evolution of hydrogen bubbles on the objects; but no deposition of copper, or only a slight one, takes place, which besides has the tendency to peel off. If this phenomenon appears after adding potassium cyanide, the excess can be readily removed by the addition of copper salt, best cyanide of copper, stirred with a small quantity of the bath to a thinly fluid paste. After each addition, a test is made whether an object suspended in the bath is rapidly and regularly coppered; if such is not the case, the addition of cyanide of copper is repeated until the bath works in a faultless and correct manner. On the other

hand, a deposit may not be formed for the want of potassium cyanide, which is already indicated by a thick formation of slime on the anodes, and by the fluid acquiring a pale blue color; or the metallic content of the bath may be too small. In the first case, a slight addition of potassium cyanide will cause the bath to work correctly, but to augment the metallic content of the bath, an addition of solution of copper cyanide in potassium cyanide is required, it being always best to introduce together with the metallic cyanide solution a small quantity of carbonate and bisulphite of soda, in order to decrease the resistance to conductivity. In every bath containing cyanide, each addition, and especially that of a metallic salt, causes a momentary irritation, and it will be found that a bath augmented by additions works irregularly for some hours. To overcome this, it is recommended to boil the bath or work it through with the current as already mentioned on p. 139.

For coppering *zinc articles*, Roseleur recommends the following bath:—

IV. Water 10 quarts, tartar, free from lime, 6.7 ozs., crystallized carbonate of soda 15 ozs., blue vitriol 6.7 ozs., caustic soda lye of 16° Bé. $\frac{3}{4}$ lb.

To prepare this bath, dissolve the tartar and the crystallized carbonate of soda in $\frac{2}{3}$ of the water, and the blue vitriol in the remaining $\frac{1}{3}$, and mix both solutions. Filter off the precipitate, dissolve it in the caustic soda lye, and add this solution to the other.

This bath works very well, and may be recommended to electro-platers who copper zinc exclusively, but where all kinds of metals are to be coppered, bath No. III. is to be preferred, it yielding equally good results for zinc.

For small zinc objects which are to be coppered in a sieve, bath No. III. is used, it being heated for this purpose, and a little more potassium cyanide added. Roseleur recommends for the same purpose a bath composed as follows:—

V. Water 10 quarts, crystallized bisulphite of soda $1\frac{3}{4}$ ozs., neutral acetate of copper 8 ozs., 75 per cent. potassium cyanide 12 $\frac{1}{4}$ ozs., and ammonia $\frac{1}{2}$ oz. The bath is prepared in the same manner as formulæ I. to III.

In preparing copper baths, the acetate of copper prescribed in the preceding formulæ may be replaced by the carbonate or sulphate, the substitution of the latter, after its previous conversion into carbonate, being of special advantage in order not to impart to the bath too great a resistance by the potassium sulphate, formed by reciprocal decomposition. The following formula is especially suitable for the use of sulphate of copper (blue vitriol):—

VI.	Blue vitriol	$10\frac{1}{2}$ ozs.
	Crystallized carbonate of soda . . .	$10\frac{1}{2}$ "
	Water	10 quarts.
	Crystallized bisulphite of soda . . .	7 ozs.
	Crystallized carbonate of soda . . .	$8\frac{1}{2}$ "
	98 to 99 per cent. potassium cyanide .	$8\frac{1}{2}$ "

First dissolve the $10\frac{1}{2}$ ozs. of blue vitriol and the $10\frac{1}{2}$ ozs. of crystallized carbonate of soda, each by itself, in hot water, and mix the two solutions; allow the precipitate of carbonate of copper to settle, and pour off the supernatant clear fluid. Then pour upon the precipitate 5 quarts of water, add the bisulphite of soda, next the carbonate of soda, and mix this solution with the solution of the potassium cyanide in 5 quarts of water. The fluid rapidly becomes clear and colorless, when it is boiled and filtered.

Of the many directions for *copper baths without potassium cyanide*, to which also belongs the bath prepared according to formula IV., and which have chiefly been proposed for coppering cast and wrought iron, only a few need be mentioned as being actually available.

Weil obtains a deposit of copper in a bath consisting of a solution of blue vitriol in an alkaline solution of tartrate of potassium or sodium. Such a bath is composed as follows:—

VII. Water 10 quarts, potassium sodium tartrate (Rochelle salt) 53 ozs., blue vitriol $10\frac{1}{2}$ ozs., 60 per cent. caustic soda 28 ozs.

The chief purpose of the large content of caustic soda is to keep the tartrate of copper, which is almost insoluble in water, in

solution. According to Weil, the coppering may be executed in three different ways, as follows:—

The iron articles tied to zinc wires or in contact with zinc strips are brought into the bath; the coppering thus taking place by contact. *Or* porous clay cells are placed in the bath containing the articles; these clay cells are filled with soda lye in which zinc plates connected with the object-rods are allowed to dip, the arrangement in this case forming an element with which, by the solution of the zinc in the soda lye, a current is produced, which effects the decomposition of the copper solution and the deposition. When saturated with zinc the soda lye becomes ineffective, and, according to Weil, it may be regenerated by the addition of sodium sulphide, which separates the dissolved zinc as zinc sulphide. *The third method of coppering* consists in the use of the current of a battery or of a dynamo-machine, in which case copper anodes have, of course, to be employed.

A copper bath recommended by Walenn is composed of a solution of equal parts of tartrate of ammonia and potassium cyanide, in which 3 to 5 per cent. of copper (in the form of blue vitriol or moist cupric hydrate) is dissolved. The bath is to be heated to about 140° F.

Copper bath according to Pfanhauser.—Dissolve $2\frac{3}{4}$ ozs. of cyanide of copper, $1\frac{1}{8}$ drachms each of pure 100 per cent. potassium cyanide and crystallized sal ammoniac, and $5\frac{1}{2}$ drachms of ammonia soda in 1 quart of lukewarm water, stirring constantly until all the salts are dissolved.

The temperature of the bath should be between 68° and 77° F., and the strength of current 3 volts. Density of current 0.5 ampère. In case the bath should become poor in metal, cyanide of copper has to be added. When the copper anodes become coated with too great an abundance of green slime, which does not decrease during the night when the bath is not working, some potassium cyanide, about $\frac{1}{2}$ drachm per quart, should be added.

Gauduin's copper bath consists of a solution of oxalate of copper with oxalate of ammonia and free oxalic acid. Fontaine asserts that the bath works well, when heated to between 140° and 150° F.

Copper baths containing cyanide cannot be brought into pitched vats, vats of stoneware or enamelled iron being used for smaller baths, and for larger, basins of brick set in cement, or iron reservoirs lined with ebonite.

Execution of coppering.—The general rules given under nickelling, as regards the suitable composition of the bath, correct selection of anodes, careful scouring and pickling of the objects and proper current-strength also apply to coppering.

As previously mentioned, annealed sheets of pure copper are used as anodes, the surface of which should be at least twice as large as that of the objects to be coppered. Even with a correct content of potassium cyanide in the bath the anodes readily tarnish and must from time to time be brightened by scouring with sand or by pickling; if the latter method be adopted, care should be had not to inhale the escaping vapors, which contain prussic acid.

The preliminary scouring and pickling of the articles to be coppered are executed according to the directions given on page 131. The same precautions discussed under nickelling have to be used in suspending the objects in the bath, and the directions given there for the suitable arrangement of the anodes, etc., also apply to coppering; however, a copper bath conducting better than a nickel bath, the distance between the anodes and the objects may, if necessary, be somewhat greater.

With a proper arrangement of the anodes and correct regulation of the current, the objects should be entirely coated with copper in a few minutes after being hung in the bath. In five to ten minutes the objects are taken from the bath and brushed with a scratch-brush of not too hard brass wires, whereby the deposit should everywhere show itself to be durable and adherent. Defective places are especially thoroughly scratch-brushed, scoured, and pickled; the objects are then returned to the bath. For solid and heavy coppering the objects remain in the bath until the original lustre and red tone of the coppering disappear and pass into a dull discolored brown; at this stage the objects are again scratch-brushed until they show lustre and the red copper color, whereby it is of advantage to moisten them with tartar water. They are then again returned to the bath, where they remain until

the dull discolored tone reappears. They are then taken out, scratch-brushed bright, rinsed in several clean waters, plunged into hot water, and finally dried, first in sawdust and then thoroughly, at a high temperature, in the drying chamber. Special attention must be paid to the thorough washing of the coppered objects, because, if anything of the bath containing cyanide remains in the depressions or pores, *small, dark, round stains* appear on those places which cannot be removed, or at least only with great difficulty, they reappearing again in a short time after having been apparently removed. This formation of stains appears especially frequently upon coppered (as well as brassed) iron and zinc castings, which cannot be produced without pores. To prevent the formation of these stains the following method is recommended: Since the rinsing in many waters, and even allowing the objects to lie for hours in running water, offer no guarantee that every trace of fluid containing cyanide has been removed, the objects are brought into a slightly acid bath which decomposes the fluid, a mixture of 1 part of acetic acid and 50 parts of water being well adapted for the purpose. The objects are allowed to remain in this mixture for three to five minutes, when they are rinsed off in water and dipped for a few minutes in dilute milk of lime. They are finally rinsed off and dried. Coppered castings thus treated will show no stains.

O. Shultz obtained a patent for the following method for removing the hydrochloric acid from the pores, and thus preventing the formation of stains: The plated objects are placed in a room which can be hermetically closed. The air is then removed from the room by the introduction of steam of a high tension, and by means of an air-pump, and water sprinkled upon the objects. By this treatment in vacuum the fluid in the pores comes to the surface and the salt solution is removed by the water sprinkled over the articles.

After drying, the deposit of copper, if it is to show high lustre, is polished with soft wheels of fine flannel and dry Vienna lime; commercial polishing red FFF, moistened with a little alcohol, is also an excellent polishing agent for copper and all other soft metals.

As is well known, massive copper rapidly oxidizes in a humid

atmosphere, and this is the case to a still greater extent with electro-deposited copper. Hence, the coppered objects, if they are not to be further coated with a non-oxidizing metal, have to be provided with a colorless, transparent coat of lacquer (see "Lacquering").

It frequently happens that slightly coppered (as well as slightly brassed) objects, especially of zinc, after some time, become entirely white and show no trace of the deposit. This is due to the deposit penetrating into the basis-metal, as already explained on p. 140. Lacquering in this case is of no avail, the deposit also disappearing under the coat of lacquer. The only remedy against this phenomenon is a heavier deposit.

If the coppered objects are to be coated with another metal, drying is omitted, and after careful rinsing they are directly brought into the respective bath, or into the quicking pickle, if, as, for instance, in silvering, quicking has to be done. In such cases, where the copper deposit serves only as an intermediary for the reception of another metallic coating, the objects need not to be coppered as thickly, as previously described, by treating them three times in the bath. Preliminary coppering for 5 to 10 minutes suffices in all cases, which is succeeded by scratch-brushing in order to be convinced that the deposit adheres firmly and that the basis-metal is uniformly coated. The objects are then hung in the bath for 5 to 10 minutes longer with a weak current. In coppering sheet iron or sheet zinc which is to be nickelled, the sheets are taken from the bath after 3 to 5 minutes, at any rate while they still retain their lustre, scratch-brushing being in this case omitted. For coppering such sheets a current-density of 0.5 ampère with a tension of 3.5 to 4 volts is required. The treatment of copper baths, when they become inactive or exhibit other abnormal phenomena, has been referred to on p. 194; all other rules for galvanic baths given in Chap. VI. must here also be observed.

For coppering *small articles en masse* in sieves it is recommended to have the copper baths right hot; for the rest, the process is the same as that given for nickelling small articles *en masse* on p. 162.

Coppering by contact and dipping.—According to Lüdersdorff, a solution of tartrate of copper in neutral potassium tartrate serves for this purpose. A suitable modification of this bath is as follows: Heat 10 quarts of water to 140° F., add 2 lbs. of pulverized tartar (cream of tartar) free from lime, and 10½ ozs. of carbonate of copper. Keep the fluid at the temperature above mentioned until the evolution of gas due to the decomposition of the carbonate of copper ceases, and then add in small portions, and with constant stirring, pure whiting until effervescence is no longer perceptible. Filter off the fluid from the tartrate of lime separated and wash the precipitate so that the filtrate, inclusive of the wash water, amounts to 10 or 12 quarts.

Zinc is coppered in this bath by simple immersion; other metals have to be brought in contact with zinc.

To coat zinc plates with a very thin but hard layer of copper, immerse the plates in a bath composed of 100 parts of water saturated with cupric chloride—cupric chloride 40 parts, water 60—150 parts of ammonia and 3000 parts of water. For very solid coppering, the above-described bath, which is of a beautiful blue color, is used, and a saturated solution of potassium cyanide in water added until the blue of the first mixture has quite disappeared. For plates engraved with the burin or for stamped plates, it is best to use a mixture of cyanide of copper with neutral potassium sulphate, to which is added a mixture of a saturated solution of blue vitriol in water and of water saturated with cyanide of copper. The bath is ready for use when the precipitate is completely dissolved and the fluid entirely discolored.

Another contact coppering bath is that prepared according to formula VII. (p. 196), proposed by Weil. In this bath zinc is also coppered by simple immersion, and copper and iron in contact with zinc strips.

According to Bacco, a copper bath in which zinc may be coppered by immersion, and iron and other metals in contact with zinc, is prepared by adding to a saturated solution of blue vitriol, potassium cyanide solution until the precipitate of cyanide of copper which is formed is again dissolved. Then add $\frac{1}{10}$ to $\frac{1}{5}$ of the volume of liquid ammonia and dilute with water to 8° Bé.

The so-called *brush-coppering* which has been recently recom-

mended may here be mentioned. This process may be of practical advantage for coppering very large objects which by another method could only be coated with difficulty. The deposit of copper is, of course, very thin. The process is executed as follows: The utensils required are two vessels of sufficient size, each provided with a brush, preferably so wide that the entire surface of the object to be treated can be coated with one application. One of the vessels contains a strongly saturated solution of caustic soda, and the other a strongly saturated solution of blue vitriol. For coppering, the well-cleansed object is first uniformly coated with a brushful of the caustic soda solution, and then also with a brushful of the blue vitriol solution. A quite thick film of copper is immediately deposited upon the object. Care must be had not to take the brush too full and not to touch the places once gone over, the second time, as otherwise the layer of copper does not adhere firmly.

Many iron and steel objects are provided with a thin film of copper in order to give them a more pleasing appearance. For this purpose a copper solution of 10 quarts of water, $1\frac{3}{4}$ ozs. of blue vitriol, and $1\frac{3}{4}$ ozs. of pure concentrated sulphuric acid may be used. Dip the iron or steel objects, previously freed from grease and oxide, for a moment in the solution, moving them constantly to and fro; then rinse them immediately in ample water, and dry. By keeping the articles too long in the solution the copper separates in a pulverulent form and does not adhere.

Steel pens, needles, eyes, etc., may be coppered by diluting the copper solution just mentioned with double the quantity of water, moistening sawdust with the solution and revolving the latter, together with the articles to be coppered, in a wooden tumbling box (p. 109).

The *inlaying* of depressions of coppered art-castings with black may be done in different ways. Some blacken the ground by applying a mixture of spirit lacquer with lampblack and graphite, while others use oil of turpentine with lampblack and a few drops of copal lacquer. A very thin nigrosin lacquer mixed with finely pulverized graphite is very suitable for the purpose. When the lacquer is dry the elevated places which are to show the copper color are cleansed with a linen rag moistened with alcohol.

Electrolytically coppered articles may be inlaid black by coating them, after thorough scouring and pickling, with arsenic in one of the baths given under "Electro-deposition of Arsenic," and, after drying in hot water and sawdust, freeing the surfaces and profiles, which are to appear coppered, from the coating of arsenic by polishing upon a felt wheel. If this polishing is to be avoided, the portions which are not to be black may be coated with covering lacquer, and arsenic deposited upon the places remaining free.

For *coloring, platinizing, and oxidizing of copper*, see the proper chapter.

2. *Brassing* (*Cuivre-poli Deposit*).

Brass is an alloy of copper and zinc whose color depends on the quantitative proportions of both metals. The alloys known as *yellow brass, red brass* (*similor, tombac*), consist essentially of copper and zinc, while those known as *bell metal, gun metal,* and the *bronzes* of the ancients are composed of copper and tin. *Modern bronzes* contain copper, zinc, and tin.

The behavior of brass towards acids is nearly the same as that of copper; it oxidizes, however, less readily in the air, is harder than copper, malleable, and can be rolled and drawn into wire.

Brass baths.—According to the plan pursued in this work, only the most approved formulæ will be given. There exists a large number of directions for brass baths; but we share the opinion of Roseleur, that a brass bath containing copper and zinc salts in nearly equal proportions is the most suitable and least subject to disturbances. A brass bath is to be considered as a mixture of solutions of cyanide of copper and cyanide of zinc, or of other copper-zinc salts in the most suitable solvent; and since a solution of cyanide of copper requires a different current-strength from one of zinc salt, it will be seen that according to the greater or smaller current-strength, now more of the one, and now more of the other metal is deposited, which, of course, influences the color of the deposit. Hence the proper regulation of the current is the chief condition for obtaining beautiful deposits, let the bath be composed as it may.

For all baths containing more than one metal in solution, it may be laid down as a rule that the less positive metal is first deposited. In a brass bath copper is the negative and zinc the positive metal; and hence a *weaker* current deposits more copper, in consequence of which the deposit becomes redder, while, *vice versa*, a *more powerful* current decomposes besides the copper solution also a larger quantity of zinc solution and reduces zinc, the color produced being more pale yellow to greenish. By bearing this in mind it is not difficult to obtain any desired shades within certain limits.

I. *Brass bath according to Roseleur.*—Blue vitriol and zinc sulphate (white vitriol), of each $5\frac{1}{4}$ ounces, and crystallized carbonate of soda $15\frac{3}{4}$ ounces. Crystallized carbonate of soda and crystallized bisulphite of soda, of each 7 ounces, 98 per cent. potassium cyanide $8\frac{3}{4}$ ounces, arsenious acid $30\frac{3}{4}$ grains, water 10 quarts.

The bath is prepared as follows: In 5 quarts of warm water dissolve the blue vitriol and the zinc sulphate; and in the other 5 quarts the $15\frac{3}{4}$ ounces of carbonate of soda; then mix both solutions, with stirring. A precipitate of carbonate of copper and carbonate of zinc is formed, which is allowed quietly to settle for 10 to 12 hours, when the supernatant clear fluid is carefully poured off, so that nothing of the precipitate is lost. Washing the precipitate is not necessary; the clear fluid poured off is of no value and is thrown away. Now add to the precipitate so much water that the resulting fluid amounts to about 6 quarts, and dissolve in it, with constant stirring, the carbonate and bisulphite of soda, adding these salts, however, not at once, but gradually, in small portions, to avoid foaming over by the escaping carbonic acid. Dissolve the potassium cyanide in 4 quarts of cold water and add this solution, with the exception of about $\frac{1}{2}$ pint, in which the arsenious acid is dissolved with the assistance of heat, to the first solution, and finally add the solution of arsenious acid in the $\frac{1}{2}$ pint of water retained, when the bath should be clear and colorless. If after continued stirring particles of the precipitate remain undissolved, carefully add somewhat more potassium cyanide until solution is complete.

Fresh brass baths work, as a rule, more irregularly than any

other baths containing cyanide, the deposit being either too red or too green or gray, while frequently one side of the object is coated quite well, and the other not at all. To force the bath to work correctly it must be thoroughly boiled, the water which is lost by evaporation being replaced by the addition of distilled water or pure rain water. If boiling is to be avoided, the bath, as previously mentioned, is worked through for hours, and even for days, with the current, until an object suspended in it is correctly brassed.

The addition of a small quantity of arsenious acid is claimed to make the brassing brighter; but the above mentioned proportion of 30¾ grains for a 10 quart bath must not be exceeded, as otherwise the color of the deposit would be too light and show a gray tone.

II. Crystallized carbonate of soda 10½ ounces, crystallized bisulphite of soda 7 ounces, neutral acetate of copper 4.4 ounces, crystalized chloride of zinc 4.4 ounces, 98 per cent. potassium cyanide 14.11 ounces, arsenious acid 30¾ grains, water 10 quarts.

The preparation of this bath is more simple than that of the preceding.

Dissolve the carbonate and bisulphite of soda in 4 quarts of water, then mix the acetate of copper and chloride of zinc with 2 quarts of water, and gradually add this mixture to the solution of the soda salts. Next dissolve the potassium cyanide in 4 quarts of water, and add this solution to the first, retaining, however, a small portion of it, in which dissolve the arsenious acid with the assistance of heat. Finally add the arsenious acid solution, when the bath will become clear. Boiling the bath, or working it through with the current, is also required.

For brassing *iron* in this bath the addition of carbonate of soda may be increased up to 35 ounces for a 10 quart bath, this being also permissible, when frequent scratch-brushing is to be avoided in coating zinc articles with a heavy deposit of brass; because it seems that a large content of carbonate of soda in the bath considerably retards the changing of the brass color into a discolored brown, though the brilliancy of the deposit appears to suffer somewhat. When boiled from 1 to 2 hours, or worked through with the current for 10 to 12 hours, the bath prepared according to

formula II. works very well; it requires a current of 0.5 to 0.55 ampère, with a tension of 3.5 to 4 volts per $15\frac{1}{2}$ square inches surface.

As previously mentioned, the color of the deposit depends on the proportional quantity in which copper and zinc are present, a strong current depositing more zinc and a weak current more copper. By diminishing or increasing the current-strength by means of the resistance board, a deposit of a redder or more pale yellow to greenish color can be produced. However, with a bath which does not contain copper and zinc in the correct proportional quantities, and especially with old baths long in use, a determined color of the deposit cannot be produced with the assistance of the resistance board. In such case the content of the metal lacking in the bath, which is required for the production of a determined color, must be augmented by the addition of solution of the respective metallic salt in potassium cyanide.

Suppose a bath which originally contained copper and zinc salts in equal proportions has been long in daily use. Now, since brass contains more copper than zinc, it is evident that more of the former will be withdrawn from the bath than of the latter, and finally a limit will be reached when the bath with a current suitable for the decomposition of the solution will deposit a greenish or gray brass, and with a weaker current produce no deposit whatever. The only help in such a case is the addition of sufficient solution of cyanide of copper in potassium cyanide, so that, even with quite a powerful current, a deposit of a beautiful brass color is produced, the shades of which can then again be controlled with the help of the resistance board. However, it must not be forgotten that every addition of a metallic salt momentarily irritates the brass bath, making it, so to say, sick, and to confine this phenomenon to the narrowest limit, an addition of carbonate and bisulphite of soda should at the same time be made, and the bath be worked through with the current as previously described, until a test shows that it works in a regular manner.

Annealed sheets of brass not rolled too hard, and of as nearly as possible the same composition and color the deposit is to show, are used as anodes. The anode-surface should be at least twice

as large as that of the objects to be brassed, though it is best to use as many anodes as the anode-rods will hold.

As in the copper bath, an abundant formation of slime on the anodes indicates the want of potassium cyanide in the bath. In this case the evolution of gas bubbles on the objects is very slight, and the deposit forms slowly. This is remedied by an addition of potassium cyanide. The slow formation of the deposit, however, may also be due to a want of metallic salts; in this case not only potassium cyanide, but also solution of cyanide of copper and cyanide of zinc in potassium cyanide, has to be added. For this purpose prepare a concentrated solution of potassium cyanide in water, and a solution of equal parts of blue vitriol and zinc sulphate in water. From the latter precipitate the copper and zinc as carbonates with a solution of carbonate of soda as given in formula I., p. 204. After allowing the precipitate to settle pour off the clear supernatant fluid and add to the precipitate, with vigorous stirring, of the potassium cyanide solution, until it is dissolved; if heating takes place thereby, add from time to time a little cold water. Add this solution with a small excess of potassium cyanide, and the addition of carbonate or bisulphite of soda, to the bath, and boil the latter or work it through with the current. A more simple method is to procure cyanide of copper and cyanide of zinc, or concentrated solutions of these combinations, from a dealer in such articles. In the first case rub in a mortar equal parts of cyanide of zinc and cyanide of copper with water to a thickly fluid paste. Pour this paste into potassium cyanide solution, containing about 7 ozs. of potassium cyanide to the quart, as long as the metallic cyanides dissolve quite rapidly with stirring. When solution takes place but slowly, stop the addition of paste.

When a brass bath contains too large an excess of potassium cyanide, a very vigorous evolution of gas takes place on the objects, but the deposit is formed slowly or not at all; besides the deposit formed has a tendency to peel off in scratch-brushing. In this case the injurious excess has to be removed, which is effected by pouring, with vigorous stirring, a quantity of the cyanide above-mentioned thinly fluid paste of cyanide of zinc and of copper into the bath.

III. Crystallized carbonate of soda 10½ ozs., crystallized bisulphite of soda 7 ozs., cyanide of copper and cyanide of zinc of each 3½ ozs., water 10 quarts, and enough 98 per cent. potassium cyanide to render the solution clear.

To prepare the bath dissolve the carbonate and bisulphite of soda in 2 to 3 quarts of water, rub in a porcelain mortar the cyanide of copper and cyanide of zinc with a quart of water to a thin paste, add this paste to the solution of the soda salts and finally add, with vigorous stirring, concentrated potassium cyanide solution until the metallic cyanides are dissolved. Dilute the volume to 10 quarts, and, for the rest, proceed as given for formulæ I. and II.

For *brassing zinc* exclusively, Roseleur recommends the following bath :—

IV. Dissolve 9¾ ozs. of crystallized bisulphite of soda and 14 ozs. of 70 per cent. potassium cyanide in 8 quarts of water, and add to this solution one of 4¾ ozs. each of neutral acetate of copper and crystallized chloride of zinc, 5½ ozs. of aqua ammonia, and 2 quarts of water.

For *brassing cast-iron, wrought-iron, and steel,* Gore highly recommends the following composition :—

V. Dissolve 35¼ ozs. of crystallized carbonate of soda, 7 ozs. of crystallized bisulphite of soda, 13¼ ozs. of 98 per cent. potassium cyanide in 8 quarts of water; then add, with constant stirring, a solution of fused chloride of tin 3½ ozs., and neutral acetate of copper 4¼ ozs., in 2 quarts of water. Boil and filter. This bath works best with a current of 3.75 volts.

According to Norris and Johnson, a good brass bath is said to be obtained as follows :—

VI. Carbonate of ammonia 35¼ ozs., 70 per cent. potassium cyanide 35¼ ozs., cyanide of copper and cyanide of zinc, each 2¼ ozs., water 10 quarts.

The large content of potassium cyanide in this bath is unintelligible.

A solution for *transferring any copper-zinc alloy serving as anode* is composed, according to Hess, as follows :—

VII. Bisulphite of soda 14¾ ozs., crystallized sal ammoniac 9½ ozs., 98 per cent. potassium cyanide 2½ ozs., water 10 quarts.

Cast metal plates are to be used as anodes. The transfer begins after a medium strong current has, for a few hours, passed through the bath. This bath is also well adapted for the deposition of tombac, with the use of tombac anodes; and the most suitable tension of the current is 3 to 3.5 volts.

VIII. For brassing all kinds of metals Wm. Pfanhauser, of Vienna, recommends the following bath :—

Dissolve $1\frac{1}{2}$ ozs. each of cyanide of copper and cyanide of zinc, $1\frac{1}{8}$ drachms of pure 100 per cent. potassium cyanide, $1\frac{1}{8}$ drachms of crystallized sal ammoniac, and $5\frac{1}{2}$ drachms of ammonia-soda in 1 quart of lukewarm water, stirring constantly until all the salts are dissolved. The bath is ready for immediate use, and does not require boiling or previous working through with the current.

The temperature of the bath should be between 68° and 77° F. For brassing zinc the current should have a strength of $2\frac{1}{2}$ volts, for iron 3 volts, for chains 3 to $3\frac{1}{2}$ volts, and for small articles *en masse* 4 volts. Density of the current, 0.5 ampère.

From the composition of this bath it will be seen that it contains quite a large content of metal, $1\frac{1}{2}$ ozs. of cyanide of copper being equal to about $6\frac{3}{4}$ drachms of copper, and $1\frac{1}{2}$ ozs. of cyanide of zinc to about $5\frac{1}{2}$ drachms of zinc. Hence the bath contains about $12\frac{1}{4}$ drachms of brass per quart.

Brassing in this bath succeeds equally well with all kinds of metals, the result being a uniform deposit of metal while the color, even of thick deposits, is a fiery sad yellow. Small articles, which are suspended *en masse* in dipping baskets, as well as steel chains, and even cast-iron, which is notoriously difficult to brass, become rapidly coated in this bath. In case the brass anodes become coated with too great an abundance of green slime, which decreases during the night when the bath is not working, some potassium cyanide, about $1\frac{1}{2}$ drachms per quart, should be added. Of course, the bath must be supplied from time to time with additions of fresh cyanide of copper and cyanide of zinc.

Execution of brassing.—To avoid unnecessary repetition, we refer, as regards the practice of brassing, to what has been said under "Execution of Coppering," the manipulations being the

same, while the treatment of the brass baths has already been sufficiently discussed in the preceding pages.

The deposition of several metals from a common solution is not an easy task, and requires attention and experience; if, however, the directions given in this chapter are followed, the operator will be able to conduct, after short experience, the brassing process with the same success as one in which but one metal is deposited.

In brassing, the distance of the objects to be brassed from the anodes is of considerable importance. If objects with deep depressions or high reliefs are hung in the brass bath, it will be found that, with the customary distance of $3\frac{3}{4}$ to $5\frac{3}{4}$ inches from the anodes, the brassing of the portions in relief nearest to the anodes will turn out of a lighter color than that of the depressed portions, which will show a redder deposit, the reason for this being that the current acts more strongly upon the portions in relief, and consequently deposits more zinc than the weaker current, which strikes the depressions. To equalize the difference, the objects have to be correspondingly further removed from the anodes, with lamp-feet up to $9\frac{3}{4}$ inches, and even more, when a deposit of the same color will be everywhere formed.

The brassing of unground *iron castings* is especially troublesome, and in order to obtain a beautiful and clean deposit the preliminary scratch-brushing has to be executed with special care; but even then the color of the brass deposit will sometimes be found to possess a disagreeable gray tone. This is very likely largely due to the quality of the iron itself, and it is advisable first to give the casting a thin coat of nickel or tin, upon which a deposit of brass of the usual brilliancy can be produced. In baths serving for brassing iron articles, a large excess of potassium cyanide must be avoided; it is, however, an advantage to increase the content of carbonate of soda.

Brassing by contact and dipping.—Some authors have given directions for brassing by contact—for instance, Bacco, Weil, and others—but the results obtained are so unsatisfactory, and the process so uncertain, that it is not necessary to enter into further details.

The inlaying with black of brassed articles is done in the same manner as described under "Coppering."

For oxidizing, platinizing, and coloring of brass, see the proper chapter.

3. *Bronzing.*

The electrolytic coating of metallic objects with bronze, *i. e.*, a copper-tin alloy, or an alloy of copper, tin, and zinc, is but seldom practised, the bronze tone being in most cases imitated by a deposit of brass, with a somewhat larger content of copper.

For coating *wrought- and cast-iron* with bronze, Gountier recommends the following solution:—

Yellow prussiate of potash 10¼ ozs., cuprous chloride 5¼ ozs., stannous chloride (tin salt) 14 ozs., sodium hyposulphite 14 ozs., water 10 quarts.

According to Ruolz, a bronze bath is prepared as follows: Dissolve at 122° to 140° F., cyanide of copper 2.11 ozs., and oxide of tin 0.7 oz. in 10 quarts of potassium cyanide solution of 4° Bé. The solution is to be filtered.

Elsner prepares a bronze bath by dissolving 21 ozs. of blue vitriol in 10 quarts of water, and adding a solution of 2½ ozs. of chloride of tin in potash lye.

Salzède recommends the following bath, which is to be used at between 86° and 95° F.: Potassium cyanide 3½ ozs., carbonate of potash 35¼ ozs., stannous chloride (tin salt) 0.42 oz., cuprous chloride ½ oz., water 10 quarts.

Weil and Newton claim to obtain beautiful bronze deposits from solutions of the double tartrate of copper and potash, and the double tartrate of the protoxide of tin and potash, with caustic potash, but fail to state the proportions.

The above formulæ are here given with all reserve, since experiments with them failed to give satisfactory results; with Gountier's, Ruolz's, and Elsner's baths no deposit was obtained, but only a strong evolution of hydrogen, while even with a strong current Salzède's bath did not yield a bronze deposit, but simply one of tin.

The following method of preparing a bronze bath may be recommended: Prepare, each by itself, solutions of phosphate of copper

and stannous chloride (tin salt) in sodium pyrophosphate. From a blue vitriol solution precipitate, with sodium phosphate, phosphate of copper, allow the latter to settle, and after pouring off the clear supernatant fluid bring it to solution by concentrated solution of sodium pyrophosphate. On the other hand, add to a saturated solution of sodium pyrophosphate solution of tin salt as long as the milky precipitate formed dissolves. Of these two metallic solutions add to a solution of sodium pyrophosphate, which contains about 1¾ ozs. of the salt to the quart, until the precipitate appears quickly and of the desired color. For anodes, use cast bronze plates, which dissolve well in the bath. Some sodium phosphate has from time to time to be added to the bath, and if the color becomes too light, solution of copper, and if too dark, solution of tin.

For *deposits of tombac* Hess's bath (formula VII., brassing) with anodes of plate or sheet tombac can be recommended; 3 to 3.5 volts being the most suitable tension of the current for the decomposition of the bath.

For nickel bronze, see p. 186.

The execution of bronzing requires the same attention and manipulations as those given for brassing.

CHAPTER IX.

DEPOSITION OF SILVER.

Properties of silver.—Pure silver is the whitest of all known metals; it takes a fine polish, is softer and less tenacious than copper, but harder and more tenacious than gold. It is very malleable and ductile, and can be obtained in exceedingly thin leaves and fine wire. Its specific gravity is 10.48 to 10.5, according to whether it is cast or hammered. It melts at about 1832° F. It is unacted upon by the air, but in the atmosphere of towns it gradually becomes coated with a film of silver sulphide. It is rapidly dissolved by nitric acid, nitrogen dioxide being evolved; hydrochloric acid has but little action upon it even at boiling

heat; when heated with concentrated sulphuric acid it yields sulphur dioxide and silver sulphate.

Silver baths.—Only formulæ for approved baths will be given.

Silver bath for a heavy electro-deposit of silver (silvering by weight).—I. 98 per cent. potassium cyanide 14 ozs., fine silver as silver chloride 8¾ ozs., distilled water 10 quarts.

I*a.* 98 per cent. potassium cyanide 8¾ ozs., fine silver as silver cyanide 8¾ ozs., distilled water 10 quarts.

Before describing the preparation of the bath a few words may be said in regard to the old dispute whether it is preferable to use silver cyanide or silver chloride. Without touching upon all the arguments advanced, it may be asserted by reason of conscientious comparative experiments that the results are the same and that the life of the bath is also the same whether one or the other salt has been used in the original preparation. From a theoretical standpoint, silver cyanide must be given the preference; but as the disadvantages in respect to the life of the bath ascribed by some to silver chloride do not exist, it might be advisable for those who prepare their own baths to use silver chloride.

Preparation of bath I. with silver chloride.—Dissolve 14 ozs. of chemically pure nitrate of silver, best the crystallized and not the fused article, in 5 quarts of water, and add to the solution pure hydrochloric acid or common salt solution, with vigorous stirring or shaking, until a sample of the fluid filtered through a paper filter forms no longer a white caseous precipitate of silver chloride when compounded with a drop of hydrochloric acid. These, as well as the succeeding operations until the silver chloride is complete, have to be performed in a darkened room, as silver chloride is partially decomposed by light. Now separate the precipitate of silver chloride from the solution by filtering, using best a large bag of close felt, and wash the precipitate in the felt bag with fresh water. Continue the washing until blue litmus-paper is no longer reddened by the wash-water, if hydrochloric acid was used for precipitating, or, if common salt solution was used, until a small quantity of the wash-water on being mixed with a drop of lunar caustic solution produces only a slight milky turbidity and no precipitate. Now bring the washed silver chloride in portions from the felt bag into a porcelain mortar, rub it with water to a thin

paste and pour the latter into the potassium cyanide solution consisting of 14 ozs. of 98 per cent. potassium cyanide in 5 quarts of water, in which, with vigorous stirring, the silver chloride gradually dissolves. All the precipitated silver chloride having been brought into solution, dilute with water to 10 quarts of fluid and boil the bath, if possible, for one hour, replacing the water lost by evaporation. A small quantity of black sediment containing silver thereby separates from which the colorless fluid is filtered off. The sediment is added to the silver residues and is worked together with them for the recovery of the silver by one of the methods to be described later on.

Preparation of bath Ia. with silver cyanide.—Dissolve 14 ounces of chemically pure crystallized nitrate of silver in 5 quarts of water, and precipitate the silver with prussic acid, adding the latter until no more precipitate is produced by the addition of a few drops of prussic acid to a filtered sample of the fluid. Now filter, wash out, and proceed for the rest exactly as stated for the bath with silver chloride, except that only $8\frac{3}{4}$ ounces of potassium cyanide are taken for dissolving the silver cyanide. In working with prussic acid avoid inhaling the vapor which escapes from the liquid prussic acid, especially in the warm season of the year; and be careful the acid does not come in contact with cuts on the hands. It is one of the most rapidly acting poisons.

Cyanide of silver may also be prepared as follows: Dissolve 14 ounces of chemically pure crystallized nitrate of silver in 5 quarts of water, and add moderately concentrated potassium cyanide solution until no more precipitate is formed, avoiding, however, an excess of the precipitating agent, as it would again dissolve a portion of the cyanide of silver. The precipitated cyanide of silver is filtered off, washed and dissolved in potassium cyanide, as above described.

The bath prepared according to formula I. or I*a*., serves chiefly for thickly silvering objects of German silver; it may, however, be used for silvering other metals by weight.

Silver bath for ordinary electro-silvering.—II. 98 per cent. potassium cyanide $6\frac{1}{4}$ to 7 ounces, fine silver (as silver nitrate or chloride), $3\frac{1}{2}$ ounces; distilled water, 10 quarts.

To prepare the bath dissolve $5\frac{1}{2}$ ounces of chemically pure

crystallized nitrate of silver in 5 quarts of distilled water; in the other 5 quarts of water dissolve the potassium cyanide, and mix both solutions. Or, if chloride of silver is to be used, precipitate the solution of $3\frac{1}{2}$ ounces of the silver salt in the same manner as given for formula I.; wash the precipitated chloride of silver, and dissolve it in the potassium cyanide solution.

Vats of stoneware, enamelled iron, or lined with ebonite mass are to be used for the silver baths.

Treatment of the silver baths; silver anodes.—Frequently the error is committed of adding too much potassium cyanide to the baths. A certain excess of it must be present, and is taken into consideration in the formulæ given. For dissolving the cyanide of silver prepared from 14 ounces of nitrate of silver, as given in formula I*a.*, only about $5\frac{1}{2}$ ounces of potassium cyanide are required, and the consequence of working with such a bath devoid of all excess would be that, on the one hand, the bath would offer a considerable resistance to the current, and, on the other, that the deposit of silver would not be uniform and homogeneous. Hence with the use of a medium strong current about 30 to 35 per cent. more of potassium cyanide than fine silver is taken. In working with a stronger current, this excess would, however, be too large, in consequence of which the deposit would not adhere properly and would peel off in scratch-brushing. And again, with a weak current the baths can, without disadvantage, stand a larger excess. As a rule, however, the proportion between fine silver and potassium cyanide in the above formula may be considered as normal, and the current-strength will have to be regulated so that a deposit of fine structure, which adheres firmly, is formed. The most suitable current-strength per $15\frac{1}{2}$ square inches of surface is 0.25 to 0.15 ampère, and 0.5 to 0.75 volt tension; the tension of a Daniell element being more than sufficient for the decomposition of the silver bath. On account of the silver bath requiring a current of slight electro-motive force, the Smee element, which yields 0.48 volt, is much liked for silvering in this country and in England. The Bunsen element may, however, also be used if the surface to be silvered is made to correspond with the energy of such an element; or if a resistance board is placed in the circuit, which is advisable in all cases. On account of the slight

electro-motive force required in silvering larger surfaces of objects, the elements are not to be coupled one after the other for electro-motive force, but alongside one another for quantity. In no case must an evolution of hydrogen be perceptible on the articles, and the current must be more weakened the larger the excess of potassium cyanide in the bath.

Whether too much, or not enough, potassium cyanide is present in the bath is indicated by the appearance of the silvered objects and the properties of the deposit, as well as by the behavior of the anodes in the bath during and after silvering.

It may be accepted, as a rule, that with a moderate current the object must, in the course of 10 to 15 minutes, be coated with a thin, dull white film of silver. If this be not the case and the film of silver shows a meagre bluish-white tone, potassium cyanide is wanting. However, if, on the other hand, the dull white deposit forms within 2 to 3 minutes, and shows a crystalline structure, or a dark tone playing into gray-black, the content of potassium cyanide in the bath is too large, provided the current is not excessively strong. If copper and brass become coated with silver without the assistance of the current, the bath contains also too much potassium cyanide.

In silvering, even if the objects are to be but thinly coated, insoluble platinum anodes should never be used, but only anodes of fine silver, which are capable of keeping the content of silver in the bath quite constant. From the behavior and appearance of the anodes, a conclusion may also be drawn as to whether the content of potassium cyanide in the bath is too large or too small. If the anodes remain silver-white during silvering, it is a sure sign that the bath contains more potassium cyanide than is necessary and desirable; but if they turn gray or blackish, and retain this color after silvering when no current is introduced into the bath for a quarter of an hour or more, potassium cyanide is wanting. On the other hand, the correct content of potassium cyanide is present when the anodes acquire during the silvering process a gray tone, which, after the interruption of the current, gradually changes back to a pure white.

Potassium cyanide when found wanting should be quickly added, though never more than 30 to 37½ grains per quart of the

bath at one time, so as to avoid going to the other extreme. Too large a content of potassium cyanide is remedied by adding to the bath, with constant stirring, a small quantity of cyanide or chloride of silver rubbed with water to a thinly fluid paste, whereby the excess is rendered harmless in consequence of the formation of the double salt of silver and potassium cyanide. Instead of such addition, the current may, however, be used as a corrector, of the excess. For this purpose suspend as many silver anodes as possible to the anode-rods, but only a single anode as an object to the object-rod, and allow the current to pass for a few hours through the bath, whereby the excess of potassium cyanide is rendered innoxious by the dissolving silver.

The bath can be kept quite constant by silver anodes provided potassium cyanide be regularly added at certain intervals, and the anode-surface is equal to that of the objects to be silvered. But since, on account of the expense, a relatively small anode-surface is frequently used, the content of silver in a bath continuously worked will finally become lower, and augmentation, by the addition of silver, will be required. The manner of effecting this augmentation depends on whether the baths are used for silvering by weight or for lighter silvering, or whether the baths are worked without stopping from morning till evening. If the content of silver in baths I. and I*a*. is not to be augmented by the current itself, it is best to use exclusively solution of silver cyanide in potassium cyanide. If, however, the working of such a bath can for some time be interrupted, then add not too small a quantity of potassium cyanide to the bath, and, after hanging a small silver anode on the object-rod and a sufficient number of anodes on the anode-rods, dissolve with not too weak a current silver from the anodes until the latter, which at first remain white, begin to acquire a gray tone. Silver is, of course, deposited upon the anode suspended as an object, which is, however, not lost, it being dissolved later on when the anode is secured to the anode-rod. The quantity of silver dissolved is considerably larger than that deposited upon the small anode-surface suspended as an object.

It has previously been mentioned that with proper treatment baths made with chloride of siver have the same duration of life

as those prepared with cyanide of silver. The chief feature of such proper treatment is the augmentation of the content of silver by electrolysis, *i. e.*, by the current itself. If it were not possible to proceed in this manner, the bath, by the frequently repeated additions of solution of the chloride, instead of the cyanide of silver, in potassium cyanide, would gradually thicken by reason of the potassium chloride which is thereby simultaneously introduced, and in consequence of this would offer greater resistance to the current. The fear expressed by some that a crystalline separation of potassium chloride, and the consequent formation of a porous deposit upon the objects, might take place is erroneous, potassium chloride being one of the most soluble salts and showing but little tendency to separate in crystals from aqueous solutions. The above-mentioned gradual thickening is, however, a disadvantage, which shows itself by the deposit being less homogeneous, and for this reason it is advisable, when silvering by weight, to use silver cyanide instead of the chloride for strengthening the silver bath.

A gradual thickening of the bath may also take place if potassium cyanide containing potash is used instead of the preparation free from potash, and of 98 to 99 per cent. purity. Even pure fused potassium cyanide produces a thickening of the bath, which, however, progresses very slowly. This thickening is due to a portion of the excess of potassium cyanide being converted by the action of the air into potassium carbonate. The latter thus formed must from time to time be neutralized, which is mostly done with prussic acid, the potassium carbonate being thereby converted into potassium cyanide. Instead of prussic acid, calcium cyanide or barium cyanide may be added as long as a precipitate of calcium carbonate or barium carbonate is formed, the clear solution being separated from the precipitate by filtering.

For augmenting the content of silver in baths prepared according to formula II., solution of nitrate of silver or of chloride of silver in potassium cyanide may unhesitatingly be used, since the thickening proceeds more slowly on account of the smaller content of salt in the bath, and because a cheaper bath can be more readily renewed without the sacrifice of money than one for

heavy silvering. The recovery of silver from old baths is effected by one of the methods given later on.

To determine whether the bath contains silver and excess of potassium cyanide in proper proportions, the following method may be used: Dissolve 1 gramme (15.43 grains) of chemically pure crystallized nitrate of silver in 20 grammes (0.7 oz.) of water, and gradually add this solution, with constant stirring with a glass rod, to 100 grammes (3.52 ozs.) of the silver bath in a beaker glass as long as the precipitate of silver cyanide formed dissolves by itself. If, after adding the entire quantity of silver solution, the precipitate dissolves rapidly, too large an excess of potassium cyanide is present in the bath, and *vice versa*, if the precipitate does not completely dissolve after stirring, potassium cyanide is wanting.

While this experiment allows us to judge of the proportion of silver to potassium cyanide, it does not throw any light upon the effective content of silver in the bath, and for refreshing the latter, it is desirable to know the actual content of silver in it. To determine this, mix 25 cubic centimetres of the silver bath in a beaker glass with 50 cubic centimetres of pure hydrochloric acid and 50 cubic centimetres of water, and heat upon a water or sand bath until all odor of prussic acid has disappeared, and then dilute with 200 cubic centimetres of water. Filter off the precipitate of chloride of silver formed through a weighed filter, previously dried at 212° F., wash the precipitate with hot distilled water until the filtrate is no longer rendered turbid by a drop of silver solution (1 part of nitrate of silver to 20 of water), and dry at 212° F. until the weight remains constant. After deducting the weight of the dried filter, the weight of the precipitated chloride of silver is obtained, and from this the weight of the metallic silver is calculated according to the following formula:—

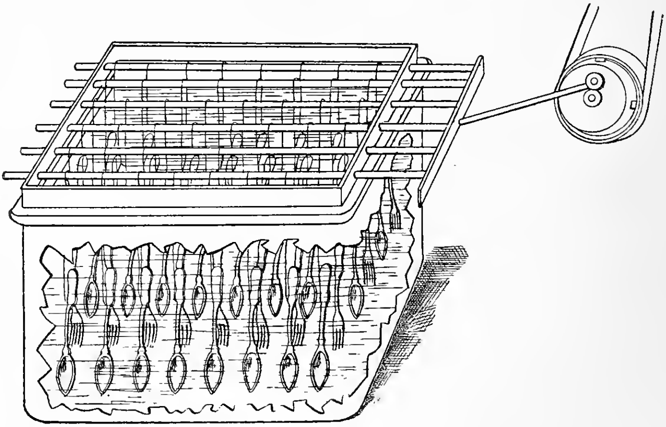
$$143.5 : 108 = \text{grammes of cloride of silver found} : x.$$

The content of silver in the bath per liter is then found by multiplying x by 40.

In silvering, the constant agitation of the layers of fluid is of decided advantage, streaks being otherwise readily formed upon the silvered objects. To keep the articles in gentle motion while

in the bath, one method is to connect the suspending rods to a frame of iron having four wheels, about 3 inches in diameter, connected to it, which slowly travel to and fro to the extent of 3 or 4 inches upon inclined rails attached to the upper edges of the tank, the motion, which is both horizontal and vertical, being given by means of an eccentric wheel driven by steam power. By another arrangement, the frame supporting the articles does not rest upon the tank, but is suspended above the bath, and receives a slow swinging motion from a small eccentric or its equivalent. In the Elkington establishment at Birmingham the following arrangement is in use: All the suspending rods of the bath rest upon a copper mounting, which, by each revolution of an eccentric wheel, is lifted about $\frac{3}{4}$ inch, and then returned to its position; the copper mounting is connected to the main negative wire of the dynamo-machine by a copper cable. The same object may also be attained by giving the objects a horizontal instead of vertical motion, as shown in Fig. 108, in which the motion is produced by an eccentric wheel on the side.

Fig. 108.



Finally it remains to mention a singular phenomenon in silvering which has not yet been explained. A small addition of certain, and especially of organic, substances, which, however, must not be made suddenly or in too large quantities, produces a fuller

and better adhering deposit of greater lustre than can be produced in fresh baths. Elkington observed that an addition of a few drops of carbon disulphide to the bath made the silvering more lustrous, while others claim to have used with success solutions of iodine in chloroform, of gutta-percha in chloroform, as well as heavy hydrocarbons, tar, oils, etc. However, many baths have been entirely spoiled by an attempt to change them into bright working baths by the addition of such ingredients; and hence it is best to leave such experiments alone. There is no doubt that a silver bath becomes better in the degree as it takes up small quantities of organic substances from dust and air. Fresh silver baths will more rapidly accommodate themselves to regular working by the addition of a few drops of spirit of sal ammoniac.

After silvering the objects frequently show, instead of a pure white, a yellow tone or they become yellow in the air, which is ascribed to the formation of basic silver salts in the deposit. To overcome this evil it has been proposed to allow the objects to remain in the bath for a few minutes after interrupting the current, whereby the basic salts are dissolved by the potassium cyanide of the bath; or the same object is attained by inverting the electrodes for a few seconds, after plating, thus transforming the articles into anodes. The electric current carries away the basic salt of silver in preference to the metal. This operation should, of course, not be prolonged, otherwise the silver will be entirely removed from the objects, and will be deposited on the anodes. For the same purpose some electro-platers hold in readiness a warm solution of potassium cyanide, in which they immerse the silvered articles for half a minute.

Execution of silvering.—A. *Silvering by weight.*—Copper, brass, and all other copper alloys may be directly silvered after amalgamating (quicking), whilst iron, steel, nickel, zinc, tin, lead, and Britannia are first coppered or brassed, and then amalgamated.

The mechanical and chemical preparation of the objects for the silvering process is the same as described on pages 126 and 131. To obtain well-adhering deposits great care must be exercised in freeing the objects from grease and in pickling. As a rule, objects to be silvered are ground and polished; but polishing must not be carried too far, since the deposit of silver does not adhere well to highly polished surfaces; and in case such highly polished objects

are to be silvered it is best to deprive them of their smoothness by rubbing with pumice powder, emery, etc., or by pickling.

The treatment of copper and its alloys, German silver and brass, which have chiefly to be considered in silvering by weight, is, therefore, as follows:—

1. *Freeing from grease* by hot potash or soda lye (1 part of caustic alkali to 8 or 10 parts of water), or by brushing with the lime-paste mentioned on page 132.

2. *Pickling* in a mixture of 1 part, by weight, of sulphuric acid of 66° Bé. and 10 of water. This pickling is only required for rough surfaces of castings, ground articles being immediately after freeing from grease treated according to 3.

3. *Rubbing* with a piece of cloth dipped in fine pumice powder or emery, after which the powder is to be removed by washing.

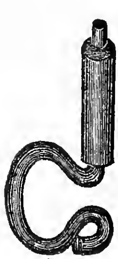
4. *Pickling* in the preliminary pickle, rinsing in hot water, and quickly drawing through the bright dipping bath (page 127), and again thoroughly rinsing in several waters.

5. *Amalgamating* (*quicking*) by immersion in a solution of mercury, called the quicking solution, and consisting of a solution of 0.35 ounce of nitrate of mercury in 1 quart of water, to which, with constant stirring, pure nitric acid in small portions is added until a clear fluid results; a weak solution of potassium-mercury cyanide in water is, however, preferable for quicking.

6. *In the quicking solution* the objects remain only long enough to acquire a uniform white coating, when they are rinsed in clean water, and gone over with a brush in case the quicking shows a gray instead of a white tone.

The objects are now brought into the silver bath and secured to the suspension rods by slinging wires of copper. For forks and spoons these wires are bent on their extremities in such a manner that the fork or spoon may readily be inserted or removed. Fig. 109 presents this terminal hook. The straight portion of these wires which dips into the liquid is covered with a small tube of India rubber or coated with ebonite mass, which prevents the useless deposit of silver upon it. The hooped portions, however, become coated with silver, which may be removed by the use of acids after having raised the India-rubber tube.

Fig. 109.



Introduce into the bath at first a somewhat more powerful current so that the first deposit of silver takes place quite rapidly, and after 3 minutes regulate the current so that in 10 to 15 minutes the objects are coated with a thin, dull film of silver. At this stage take them from the bath, and after seeing that all portions are uniformly coated with silver, scratch-brush them with a brass brush, which should, however, not be too fine. In doing this the deposit must not raise up; if at this stage the objects stand thorough scratch-brushing, raising of the deposit in burnishing later on need not be feared.

Any places which show no deposit of silver are vigorously scratch-brushed with the use of pulverized tartar, then again carefully cleansed by brushing with lime-paste to remove any impurities due to touching with the hands, pickled by dipping in potassium-cyanide solution, rinsed off again, quicked, and after careful rinsing returned to the bath. Special care must be had not to contaminate the bath with quicking solution, as this would soon spoil it.

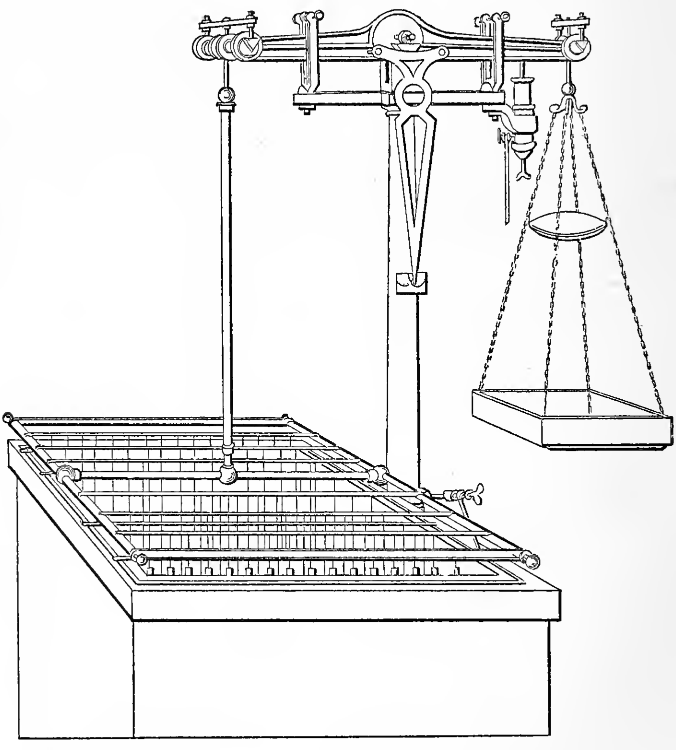
The objects now remain in the bath until the deposit has acquired a weight corresponding to the desired thickness. Knives, forks, and spoons receive a deposit of 2.11 to 3.52 ozs. of silver per dozen, such deposit being produced with elements in 10 to 14 hours, and with a dynamo-electrical machine in 4 to 5 hours. According to Dr. William H. Wahl, the amount of silver deposited upon the several grades of plated table ware manufactured by the William Rogers Manufacturing Co., of Hartford, Conn., is as follows:—

Per gross.	Extra plate.	Double plate.	Triple plate.
Teaspoons	48 dwts.	4 ozs.	6 ozs.
Desertspoons and forks .	72 "	6 "	9 "
Tablespoons and med. forks	96 "	8 "	12 "

In order to control the weight of the deposit proceed as follows: After having removed one of the pans of a sensitive beam balance, substitute for it a brass rod which keeps the other pan in equilibrium. Under this rod place a vessel filled with pure water and of sufficient diameter and depth to allow of the article suspended to the rod dipping entirely into the water without touching the sides of the vessel. Suppose now that several dozen

spoons of the same size and shape are at the same time to be provided with a deposit of a determined weight, it suffices to control the weight of the deposit of a single spoon, and when this has acquired the necessary deposit all the other spoons will also be coated with a deposit of silver of the same thickness as the test spoon. After quicking and carefully rinsing the spoons, one of them is suspended to the brass rod of the balance so that it dips entirely under water; the equilibrium is then re-established by placing lead shot upon the pan of the scale, and adding the

Fig. 110.



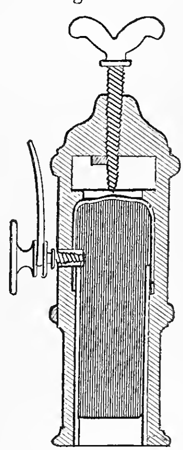
weight corresponding to the deposit the spoon is to receive. Now bring the weighed spoon together with the rest into the bath, and proceed with the silvering process in the ordinary manner. After some time the weighed spoon is taken from the bath, rinsed in

water, and hung to the brass rod of the scale; if it does not restore the equilibrium of the latter, it is returned to the bath, after some time again weighed, and so on until its weight corresponds to that of the lead shot and weight placed in the pan of the scale, when it is assumed that the balance of the articles have also received their proper quantity and that the operation is complete.

A more complete weighing apparatus is the plating balance first used by Brandely and later on improved by Roseleur. The apparatus, which is shown in Fig. 110, is designed for obtaining deposits of silver "without supervision and with constant accuracy, and which spontaneously breaks the current when the operation is terminated." It is manufactured in various sizes suitable for small or large operations.

It consists of: 1. A wooden vat, the upper edge of which carries a brass winding-rod having a binding screw at one end to receive the positive conducting wire of the battery; from this rod the anodes are suspended, which are entirely immersed in the solution, and communicate with brass cross rods by means of platinum wire hooks. These cross rods are flattened at their ends so that they may not roll, and at the same time have a better contact with the "winding-rod." 2. A cast-iron column screwed at its base to the side of the vat, and which carries near the top two projecting arms of cast-iron, the extremities of which are vertical and forked, and may be opened or closed by iron clamps. These forks are intended for sustaining the beam and preventing the knives from leaving their bearings under the influence of too violent oscillations. In the middle of the two arms are two wedge-shaped recesses of polished steel to receive the knife edges of the beam. One of the arms of the column carries at its end a horizontal ring of iron in which is fixed a heavy glass tube supporting a cup of polished iron which is insulated from the column (Fig. 111).

Fig. 111.



This cup has at its lower part a small pocket of lamb-skin or

of India rubber, which by means of a screw beneath may be raised or lowered. This flexible bottom allows the operator to lower or raise at will the level of the mercury introduced afterwards into the iron cup. Another lateral screw permits connection to be made with the negative electrode. 3. A cast-iron beam carrying in the middle two sharp knife edges of the best steel hardened and polished. At each extremity there are two parallel bearings of steel separated by a notch, and intended for the knife edges of the scale-pan that receives the weights, and those of the frame supporting the articles to be silvered. One of the arms of the beam is provided with a stout platinum wire, placed immediately above and in the centre of the cup of mercury. According as the beam inclines one way or the other, this wire plays in or out of the cup. 4. A scale-pan for weights, with two knife edges of cast-steel, which is attached to four chains supporting a wooden pan for the reception of weights. A smaller pan above is intended for the weights corresponding to that of the silver to be deposited. 5. The frame for supporting the articles to be silvered, which is also suspended from two steel knife edges, and the rod of which is formed of a stout brass tube attached below to the brass frame proper, which last is equal in dimensions to the opening of the vat, and supports the rods to which the articles are suspended.

Fig. 112 shows a Roseleur plating balance, together with the resistance board, voltmeter, and silver bath; and will be understood without further explanation.

For calculating the weight of the deposit from the density of current, see "Chemical and Electric Equivalents."

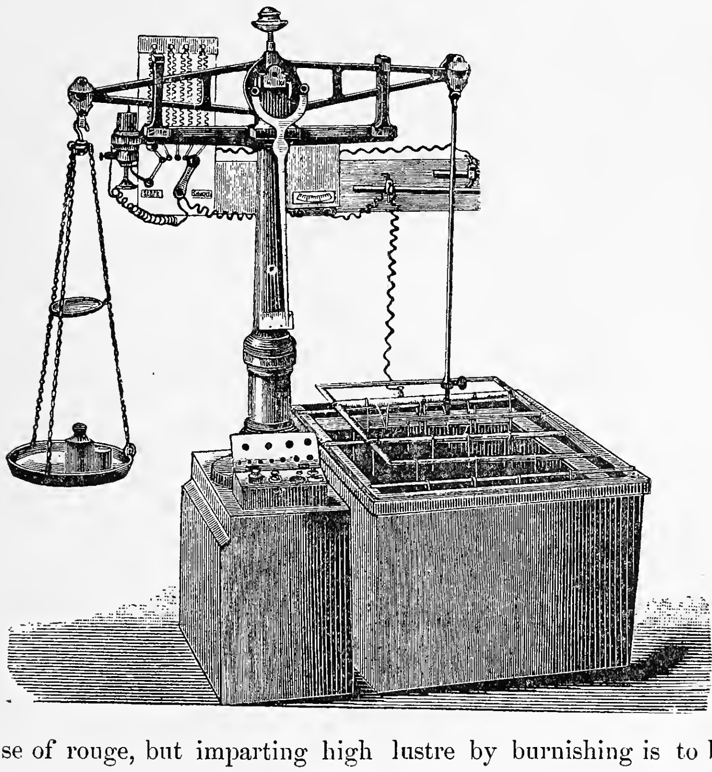
When the articles have received a deposit of the required weight, they are treated for the prevention of subsequent yellowing according to one of the methods given on p. 221, then scratch-brushed with the use of decoction of soap-root, plunged in hot water, and dried in sawdust.

Articles which are to retain the beautiful crystalline dead white with which they come from the bath are, without touching them with the fingers or knocking them against the sides of the vessel, plunged into very hot clean water and then suspended free to dry; immediately after drying they are to be provided with a thin coat

of kristalline or zapon to protect the dead white coating which readily turns yellow, and, moreover, is very sensitive.

The silvered articles having been scratch-brushed, must finally be polished, which may be effected upon a fine felt wheel with the

Fig. 112.



use of rouge, but imparting high lustre by burnishing is to be perferred, the deposit being first treated with the steel burnisher and then with the stone burnisher, as explained on p. 124. The steel burnisher consists of a piece of polished steel varying in shape mounted in a wooden handle. The operation of burnishing is very simple. Take hold of the tool very near to the steel or stone, and lean very hard with it on those parts which are to be burnished, causing it to glide by a backward and forward movement without taking it from the piece. When it is requisite that the hand should pass over a large surface at once, without

losing its point of support on the work-bench, in taking hold of the burnisher be careful to place it just underneath the little finger. By these means the work is done more quickly, and the tool is more solidly fixed in the hand. During the whole process the tool must be continually moistened with soap-suds.

In some establishments in which plated table-ware in large quantity is turned out, ingeniously devised burnishing machines driven by power are in use, by which much of the manual labor is spared. The knife, spoon, etc., each supported by its tips in a suitable holder, are very slowly rotated, while the burnishing tool moves quickly over the surface, performing the work rapidly and satisfactorily.

When the burnishing is completed, the surface is wiped off longitudinally with an old, soft calico rag; sawdust, hard cloth, and tissue paper produce streaks.

B. *Ordinary silvering.*—The operations the objects which are to receive a deposit of less thickness have to undergo, are exactly the same as those described under silvering by weight, the only difference being that for quicking a weaker solution (15 to 31 grains of nitrate of mercury to 1 quart of water) or very dilute solution of potassium-mercury cyanide is used, and that the objects remain in the bath for a shorter time. As previously mentioned, iron, steel, zinc, tin, etc., must previously be coppered or brassed; however, tin and its alloys may also be directly silvered in the silver bath, but a larger excess of potassium cyanide is required than for copper, brass, or German silver.

According to Dr. William H. Wahl, in the United States, the practice of previous coppering is not adopted either with Britannia metal or steel. The practice of different establishments of cleansing their work differs somewhat, but all aim at the same result, viz., to secure a smooth adhering coating of metal upon an inferior base.

The practice of the Meriden Britannia Co.'s works at Meriden, Conn., as observed by Dr. William H. Wahl, is substantially as follows: *With Britannia or "white metal:"* The article is first cleansed of all grease by immersion in boiling alkali; then into dilute muriatic acid; then into a "striking" solution, viz., a weak cyanide of silver solution with a large proportion of free cyanide

of potassium, and a large silver anode operated with a very strong electric current. The purpose of immersion in this solution is to effect an instantaneous deposit of silver on the metal, to better insure a perfect coating in the silver bath proper. The articles remain in the "striking" solution for a few seconds only, as its action, owing to the large proportion of free cyanide it contains, is very prompt, and as soon as they have received a thin coating, which takes place almost immediately, they are removed to the electro-plating bath, where they remain until they have received the proper coating of silver. In many cases, especially with articles of considerable size, cleansing in boiling alkali must be supplemented by scratch-brushing, in which case the acid dip may be dispensed with, and the article, after thorough rinsing and dipping in alkali to remove finger-marks, is immersed at once in the "striking" solution.

German silver or nickel articles are first cleansed in boiling alkali, washed, then dipped in a mixture of two-thirds sulphuric acid and one-third nitric acid, then into quicking solution, then into the "striking" solution, and from this into the plating bath.

Steel articles are cleansed in boiling alkali, rinsed, dipped in muriatic acid, then in the "striking" solution, and from this into the plating bath. In case the articles require scouring the acid dip is dispensed with. For *steel* two "striking" solutions are used, one somewhat richer in silver than the other, the weaker solution being used first.

With the William Rogers Manufacturing Co., Hartford, Conn., the following is the general outline of the methods in use for preparing work for plating:—

For cleansing (steel) cutlery.—Immersion in boiling alkali for the removal of grease; scouring; rinsing; dipping into strong muriatic acid; then for a few seconds in a silver "striking" solution; then in a plating bath until the required amount of silver is deposited.

The formula for the "striking" solution, which will be given later on, is low in silver, rich in cyanide, and worked with a strong current and silver anode.

Nickel-silver (German silver) for spoons.—Immerse in boiling alkali; scouring, if necessary, rinsing in water; immersion in

acid mixture, composed of two-thirds sulphuric acid and one-third nitric acid; dipping in weak quicking solution (either very dilute potassium-mercury cyanide or acidulated nitrate of mercury); immersion for a few seconds in the silver "striking" solution; and from this into the plating bath.

Britannia metal (*hollow-ware*).—Cleansing in alkali as above; rinsing in water; again immersing in alkali to remove finger-marks, if necessary, immersing in the "striking" solution, and from this into the plating solution. A quicking solution for Britannia, sometimes employed, is composed of a strong solution of sal ammoniac and corrosive sublimate, into which the articles are dipped after cleansing in potash.

The silver "striking" solution, as used by the Wm. Rogers Manufacturing Co., of Hartford, Conn., is composed as follows:—

Rogers's "striking" solution.—Cyanide of potassium 6 ozs., silver ½ oz., water 1 gallon. Use a strong current.

Meriden Company's "striking solution."—Cyanide of potassium 12 to 16 ozs., silver 8 to 10 dwts, water 1 gallon.

The plating solution commonly employed by the Wm. Rogers Manufacturing Co. has the following composition: Cyanide of potassium 6 ozs., silver (in chlorate) 4 ozs., water 1 gallon.

The usual formula of the Meriden Britannia Co. has the following proportions: Cyanide of potassium 12 ozs., silver 3 ozs., water 1 gallon.

In order to secure an extra heavy coating of silver on the convex surfaces of spoons and forks, which, being subject to greater wear than the other parts, require extra protection, the Meriden Britannia Co. uses a frame in which the articles supported therein by their tips are placed horizontally in a shallow silver bath, and immersed just deep enough to allow the projecting convexities to dip into the bath. By this artifice these portions are given a second coating of silver of any desired thickness. This mode of procedure, which is termed "sectional" plating, accomplishes the intended purpose nicely and satisfactorily. In some establishments the silvered forks and spoons are placed between plates of gutta-percha of corresponding shape, and held together by rubber bands. In these plates the portions to be provided with an extra coating of silver are cut out. By suspending the forks and spoons

thus protected in the bath, the unprotected places receive a further layer of silver, the outlines of which are later on smoothed down with burnishers.

"*Stopping off.*"—Stopping off is the manipulation by which certain parts of a metallic article, which may be already covered with an electro-deposit on its whole surface, are coated with another metal. For instance, if it is desired to gild the parts in relief of an object the other portions are "stopped off," and *vice versa.* Stopping off varnish is prepared by dissolving asphalt or dammar with an addition of mastic in oil of turpentine. Apply with a brush, and after thoroughly drying the articles in the drying chamber place them for one hour in very cold water, whereby the varnish hardens completely. After electro-plating the varnish is removed, best with benzine, the article plunged in hot water and dried in sawdust.

For a varnish that will resist the solvent power of the hot alkaline gilding liquid, Gore recommends the following composition: Translucent rosin 10 parts, yellow beeswax 6, extra-fine red sealing-wax 4, finest polishing rouge 3.

Silvering of iron.—The article to be silvered is first immersed in a warm bath of dilute hydrochloric acid, then in a solution of mercuric nitrate, and connected with the zinc pole of a Bunsen element. The iron becomes rapidly covered with a layer of mercury. It may then be brought into the silver bath and the required quantity of silver deposited on it. By heating to 572° F. the mercury separates and the silver adheres firmly to the iron. To save silver the iron may also be coated with a layer of tin. Dissolve 1 part of purified tartar in 8 parts of boiling water and connect one or more tin anodes with the carbon pole of a Bunsen element. The zinc pole is connected with a bright copper sheet and the current conducted through the bath until the copper is coated with a sufficient layer of tin. The copper is then removed and replaced by the iron article. Articles thus coated with tin and then silvered are cheaper than those produced by any other method.

Silvering by contact, by immersion, and cold silvering with paste.—For silvering by contact with zinc the bath prepared according to formula II. may be used, adding about 77 grains more of cyanide

of potassium per quart. The articles are to be prepared in the same manner as for silvering by weight and quicked in a weak quicking solution. Before placing the articles in the bath they are wrapped round with bright zinc wire, or are brought in contact while in the bath with a bright strip of zinc, care being had to frequently change the points of contact to prevent the formation of stains. As previously mentioned, by the contact of the metal to be silvered with the electro-positive zinc a weak current is produced which effects the deposition of the silver, but this taking place very slowly it is best to heat the silver bath. Silver being at the same time deposited upon the zinc, the latter must be frequently freed from the deposit and brightened by means of a file or emery paper.

By contact with zinc silver may also be deposited in one of the following baths for *silvering by immersion:* Crystallized nitrate of silver 5.64 drachms, 98 per cent. potassium cyanide 1.23 ozs., water 1 quart. To prepare the bath dissolve the silver salt in 1 pint of distilled water, then the potassium cyanide in the remaining pint of water, and mix the two solutions. The bath is heated in a porcelain or enamelled iron vessel to between 176° and 194° F., and the thoroughly cleansed and pickled objects are immersed in it until uniformly coated; previous quicking is not required. The deposit is lustrous if the articles are left but a short time in the bath, but becomes dull when they remain longer; in the first case the deposit is a mere film, and, while it is somewhat thicker in the latter, it can under no circumstances be called solid.

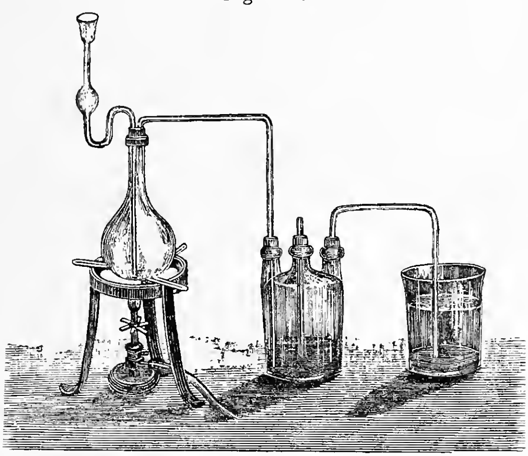
The bath gradually works less effectively and finally ceases to silver, when it may be attempted to restore its action by the addition of $2\frac{3}{4}$ to $5\frac{1}{2}$ drachms of potassium cyanide per quart. Should this prove ineffectual, the content of silver is nearly exhausted, and the bath is evaporated to dryness, and the residue added to the silver waste. Frequent refreshing of the bath with silver salt cannot be recommended, the silvering always turning out best in a fresh bath.

A solution of nitrate of silver in sodium sulphide is, according to Roseleur, very suitable for silvering by immersion. The solution is prepared by pouring into a moderately concentrated solu-

tion of sodium sulphide, with constant stirring, solution of a silver salt until the precipitate of silver sulphide formed begins to be dissolved with difficulty. This bath can be used cold or warm, fresh solution of silver being added when it commences to lose its effect. If, however, the bath is not capable of dissolving the silver sulphide formed, concentrated solution of sodium sulphide has to be added.

For the preparation of the solution of sodium sulphide, Roseleur recommends the following method:—

Fig. 113.



Into a tall vessel of glass or porcelain (Fig. 113) introduce 5 quarts of water and 4 pounds of crystallized soda, after pouring in mercury about an inch or so deep to prevent the glass tube through which the sulphurous acid is introduced from being stopped up by crystals. The sulphurous acid is evolved by heating copper turnings with concentrated sulphuric acid, washing the gas in a Woulff bottle filled an inch or so deep with water, and introducing it into the bottle containing the soda solution, as shown in the illustration. A part of the soda becomes transformed into sodium sulphide, which dissolves, and a part is precipitated as carbonate. The latter, however, is transformed into sodium sulphide by the continuous action of sulphurous acid, and carbonic acid gas escapes with effervescence. When all has be-

come dissolved the passage of sulphurous acid should be continued until the liquid slightly reddens blue litmus-paper, and then allowed to stand aside for 24 hours. At the end of that time a certain quantity of crystals will be found upon the mercury, and the liquid above, more or less colored, constitutes the sodium sulphide of the silvering bath. The liquid sodium sulphide thus prepared should be stirred with a glass rod to eliminate the carbonic acid which may still remain in it. The liquid should then be again tested with litmus-paper; and if the blue color is strongly reddened, carbonate of soda is cautiously added, little by little, in order to neutralize the excess of sulphurous acid. On the other hand, if red litmus-paper becomes blue, too much alkali is present, and more sulphurous acid gas must be passed through the liquid, which is in the best condition for our work when it turns litmus-paper violet or slightly red. The solution should mark from 22° to 26° Bé., and should not come in contact with iron, zinc, tin, or lead.

As will be seen, this mode of preparing the sodium sulphide solution is somewhat troublesome, and it is, therefore, recommended to proceed as follows: Prepare a saturated solution of commercial sodium sulphide; the solution will show an alkaline reaction, the commercial salt frequently containing some sodium carbonate. To this solution add, with stirring, solution of bisulphite of sodium saturated at 122° F., until blue litmus-paper is slightly reddened. Then add to this solution concentrated solution of nitrate of silver until the flakes of silver sulphide separated begin to dissolve with difficulty.

The immersion bath, prepared according to one or the other method, works well and has the advantage of producing silvering of a beautiful lustre, such as is desirable for many cheap articles. By allowing the articles to remain for a longer time in the bath, the lustrous deposit becomes dull. For the production of a lustrous coating the bath should always be used cold. It must further be protected, as much as possible, from the light, as otherwise gradual decomposition takes place.

According to Dr. Ebermayer, the composition of a silver bath for immersion is as follows: Dissolve 1.12 ounces of nitrate of silver in water, and precipitate the solution with caustic potash;

then thoroughly wash the precipitated silver oxide, and dissolve it in 1 quart of water, which contains 3.52 ounces of potassium cyanide in solution; and finally dilute the whole with 1 quart more of water. For silvering, the bath is heated to the boiling-point, and the silver withdrawn may be replaced by the addition of moist silver oxide as long as complete dissolution takes place. When the silvering is no longer beautiful and of a pure white color, the bath is useless, and is then evaporated. Experiments with a bath prepared according to the above directions were not satisfactory, the coating being dull and adhering badly.

For silvering articles, especially those composed of the various alloys of copper, without the use of a current, the following process is recommended in "*Edelmetallindustrie*:" Dissolve silver in nitric acid with the assistance of the sand or water bath, and convert it into chloride of silver by carefully adding hydrochloric acid or common salt solution until, after repeated stirring and allowing to settle, no more precipitate is formed. Now let the mixture rest, then pour off the supernatant fluid and wash the white caseous precipitate until litmus-paper is no longer reddened by the wash-water. Keep the chloride of silver thus obtained in wide-mouthed black bottles. Now prepare two baths in glazed pots as follows: 1. A potassium cyanide bath by dissolving $11\frac{1}{4}$ drachms of chloride of silver and 2 ozs. of potassium cyanide in about 10 quarts of water and heating the mixture to the boiling-point. 2. A salt bath consisting of 10 quarts of water, 11 lbs. of common salt, 11 lbs. of cream of tartar, and $4\frac{1}{2}$ ozs. of chloride of silver. Boil the mixture, with constant stirring, for one hour, and when cold pour it into another pot in which it may be kept. The articles to be silvered are cleansed by treating them with dilute hydrochloric acid. They are next pickled by dipping them in nitric acid and finally plunged into a *bright-dipping bath* consisting of nitric acid, a small quantity of hydrochloric acid, and a trace of lampblack. They are then thoroughly rinsed off, and thrown into water containing a small quantity of cream of tartar, where they remain until they are to be silvered. The water must not be warm and the articles should not remain in it too long, otherwise they will tarnish and it would be impossible to obtain a pure silvering. The articles thus prepared are first

brought into the potassium cyanide bath and gently agitated, when they become immediately coated with a thin film of silver. They are then rinsed and brought into a dilute salt bath, prepared by adding water to a portion of the salt bath given under 2 (p. 235), where they remain until they have acquired a gray-white or yellowish-white color. They are then rinsed, returned to the potassium cyanide bath, again rinsed, and thrown in clean water, or dried in sawdust. Each rinsing must be effected in a different vessel. The two baths are very lasting and require only a periodical addition of potassium cyanide (when the articles on being immersed become black, which slowly turns to white) or of chloride of silver (when the articles show a yellowish-white color). When the dilute salt bath becomes too weak a fresh quantity of the salt bath is added by means of a wooden spoon. The potassium cyanide bath must be shaken every day. During the process of silvering the potassium cyanide bath is to be kept at between 176° and 194° F., and the salt bath at above 212° F. The potassium cyanide bath should only be boiled before use, when making a fresh addition of potassium cyanide or chloride of silver. The silvering obtained with the use of these baths is pure white, cheap, and durable.

The process of coating with a thin film, or rather coloring with silver, small articles such as hooks and eyes, pins, etc., differs from the above-described immersion process, which effects the silvering in a few seconds, in that the articles require to be boiled for a longer time. The process is as follows: Prepare a paste from 14.11 drachms of nitrate of silver, precipitated as chloride of silver; 44 ounces of cream of tartar, and a like quantity of common salt, by precipitating the solution of the nitrate of silver with hydrochloric acid, washing the chloride of silver and mixing it with the above-mentioned quantities of cream of tartar and common salt, and sufficient water to a paste, which is kept in a dark glass vessel to prevent the chloride of silver from being decomposed by the light. Small articles of copper or brass are first freed from grease, and pickled. Then heat in an enamelled kettle 3 to 5 quarts of rain-water to the boiling-point; add 2 or 3 heaping tablespoonfuls of the above-mentioned paste, and bring the metallic objects contained in a stoneware sieve into the bath

and stir them diligently with a rod of glass or wood. Before placing a fresh lot of articles in the bath additional silver paste must be added. If finally the bath acquires a greenish color, caused by dissolved copper, it is no longer suitable for the purpose, and is then evaporated and added to the silver residues.

Cold silvering with paste.—In this process, an argentiferous paste, composed as given below, is rubbed, by means of the thumb, a piece of soft leather or rag, upon the cleansed and pickled metallic surface (copper, brass, or other alloys of copper) until it is entirely silvered. The paste may also be rubbed in a mortar with some water to a uniform thinly fluid mass, and applied with a brush to the surface to be silvered. By allowing the paste to dry naturally, or with the aid of a gentle heat, the silvering appears. The application of the paste by means of a brush is chiefly made use of for decorating with silver articles thinly gilded by immersion. For articles not gilded, the above-mentioned rubbing on of the stiff paste is to be preferred.

Composition of argentiferous pastes.—I. Silver in the form of freshly precipitated chloride of silver *0.35 oz., common salt 0.35 oz., potash 0.7 oz., whiting 0.52 oz., and water a sufficient quantity to form the ingredients into a stiff paste.

II. Silver in the form of freshly precipitated chloride of silver* 0.35 oz., potassium cyanide 1.05 oz., sufficient water to dissolve these two ingredients to a clear solution, and enough whiting to form the whole into a stiff paste. This paste is also excellent for polishing tarnished silver; it is, however, poisonous.

The following composition, which is not poisonous, does excellent service: Silver in the form of chloride of silver 0.35 oz., cream of tartar 0.7 oz., common salt 0.7 oz., and sufficient water to form the mixture of the ingredients into a stiff paste.

Another composition is as follows: Chloride of silver 1 part, pearl-ash 3, common salt $1\frac{1}{2}$, whiting 1, and sufficient water to form a paste. Apply the latter to the metal to be silvered and rub with a piece of soft leather. When the metal is silvered, wash in water to which a small quantity of washing soda has been added.

Graining.—In gilding parts of watches, gold is seldom directly applied upon the copper; there is generally a preliminary opera-

* From 0.56 oz. of nitrate of silver.

tion called graining, by which a grained and slightly dead appearance is given to the articles. Marks of the file are obliterated by rubbing upon a whetstone, and lastly upon an oil-stone. Any oil or grease is removed by boiling the parts for a few minutes in a solution of 10 parts of caustic soda or potash in 100 of water, which should wet them entirely if all the oil has been removed. The articles being threaded upon a brass wire, cleanse them rapidly in the acid mixture for a bright lustre, and dry them carefully in white-wood sawdust. The pieces are fastened upon the even side of a block of cork by brass pins with flat heads. The parts are then thoroughly rubbed over with a brush entirely free from grease, and dipped into a paste of water and very fine pumice-stone powder. Move the brush in circles, in order not to rub one side more than the other; thoroughly rinse in cold water, and no particle of pumice-stone should remain upon the pieces or the cork. Next place the cork and the pieces in a weak mercurial solution, composed of water $2\frac{1}{2}$ gallons, nitrate or binoxide of mercury $\frac{1}{14}$ oz., sulphuric acid $\frac{1}{7}$ oz., which slightly whitens the copper. The pieces are passed quickly through the solution and then rinsed. This operation gives strength to the graining, which without it possesses no adherence.

The following preparations may be used for graining: I. Silver in impalpable powder 2 ozs., finely pulverized cream of tartar 20 ozs., common salt 4 lbs. II. Silver powder 1 oz., cream of tartar 4 to 5 ozs., common salt 13 ozs. III. Silver powder, common salt, and cream of tartar, equal parts by weight of each. The mixture of the three ingredients must be thorough and effected at a moderate and protracted heat. The graining is the coarser the more common salt there is in the mixture, and it is the finer and more condensed as the proportion of cream of tartar is greater, but it is then more difficult to scratch-brush. The silver powder is obtained as follows: Dissolve in a glass or porcelain vessel $\frac{2}{3}$ oz. of crystallized nitrate of silver in $2\frac{1}{2}$ gallons of distilled water, and place 5 or 6 ribbands of cleansed copper, $\frac{3}{4}$ inch wide, in the solution. These ribbands should be long enough to allow of a portion of them being above the liquid. The whole is kept in a dark place, and from time to time stirred with the copper ribbands. This motion is sufficient to loosen the

deposited silver, and present fresh surfaces to the action of the liquor. When no more silver deposits on the copper the operation is complete, and there remains a blue solution of nitrate of copper. The silver powder is washed by decantation or upon a filter until there remains nothing of the copper solution.

For the purpose of graining, a thin paste is made of one of the above mixtures and water, and spread by means of a spatula upon the watch parts held upon the cork. The cork itself is placed upon an earthenware dish, to which a rotating movement is imparted by the left hand. An oval brush with close bristles, held in the right hand, rubs the watch parts in every direction, but always with a rotatory motion. A new quantity of paste is added two or three times and rubbed in the manner indicated. The more the brush and cork are turned the rounder becomes the grain, which is a good quality, and the more paste added the larger the grain. When the desired grain is obtained the pieces are washed and scratch-brushed. The brushes employed are of brass wire, as fine as hair and very stiff and springy. It is necessary to anneal them upon an even fire to different degrees; one soft or half-annealed for the first operation or uncovering the grain; one harder for bringing up the lustre; and one very soft or fully annealed, used before gilding for removing any marks which may have been made by the preceding tool, and for scratch-brushing after gilding, which, like the graining, must be done by giving a rotatory motion to the tool. If it happens that the same watch part is composed of copper and steel, the latter metal requires to be preserved against the action of the cleansing acids and of the graining mixture by a composition called *resist*. This consists in covering the pinions and other steel parts with a fatty composition which is sufficiently hard to resist the tearing action of the bristle and wire brushes, and insoluble in the alkalies of the gilding bath. A good composition is: Yellow wax 2 parts by weight, translucent rosin $3\frac{1}{2}$, extra fine red sealing-wax $1\frac{1}{3}$, polishing rouge 1. Melt the rosin and sealing-wax in a porcelain dish, upon a water-bath, and afterwards add the yellow wax. When the whole is thoroughly fluid, gradually add the rouge and stir with a wooden or glass rod. Withdraw the heat but continue the stirring until the mixture becomes solid, otherwise all the

rouge will fall to the bottom. The flat parts to receive this resist are slightly heated and then covered with the mixture, which melts and is easily spread. For covering steel pinions employ a small gouge of copper or brass fixed to a wooden handle. The metallic part of the gouge is heated upon an alcohol lamp, and a small quantity of resist is taken with it. The composition soon melts, and by turning the tool around the steel pinion thus becomes coated. Use a scratch-brush with long wires, as their flexibility prevents the removal of the composition. When the resist is to be removed after gilding, put the parts into warm oil or tepid turpentine, then into a very hot soap-water or alkaline solution; and, lastly, into fresh water. Scratch-brush and dry in warm, white wood sawdust. The holes of the pinions are cleansed and polished with small pieces of very white, soft wood, the friction of which is sufficient to restore the primitive lustre. The gilding of parts of copper and steel requires the greatest care, as the slightest rust destroys their future usefulness. Should some gold deposit upon the steel, it should be removed by rubbing with a piece of wood and impalpable pumice dust, tin-putty, or rouge.

The gilding of the grained watch parts is effected in a bath prepared according to formula I. or III., given under "Deposition of Gold."

The *silvering of fine copper wire* is effected in an apparatus similar to that shown on page 179, a reservoir containing potassium cyanide solution for pickling the cleansed wire being added and placed in front of the silver bath. Lustre is imparted to the silvered wire by drawing through a draw-plate. Further details will be given under "Gilding."

Incrustations with silver, gold, and other metals.—By incrusting is understood the inlaying of depressions, produced by engraving or etching upon a metallic body, with silver, gold, and other metals, such as Japanese incrustations, which are made by mechanically pressing the silver or gold into the depressions. Such incrustations, however, can also be produced by electro-deposition, the process being as follows: The design which is to be incrusted upon a metal is executed with a pigment of white-lead and glue-water or gum-water. The portion not covered by the design is then coated with stopping-off varnish. The article is next placed

in dilute nitric acid, whereby the pigment is first dissolved, and next the surface etched, which is allowed to progress to a certain depth. Etching being finished, the article is washed in an abundance of water and immediately brought into a silver or gold bath, in which by the action of the current the exposed places are filled up with metal. This being done, the "stopping-off" varnish is removed with benzine, the surface ground smooth and polished. In this manner one article may be incrusted with several metals; for instance, brass may be incrusted with copper, silver, and gold, and by oxidizing or coloring portions of the copper beautiful effects can be produced. The principal requisites for these incrustations are manual skill and much patience; expensive apparatus is not required, every skilled electro-plater being able to execute the work.

Niel or nielled silvering.—By nielling is understood the inlaying of designs, produced either by engraving or stamping, with a black mixture of metallic sulphides. For preparing the nielling composition a certain proportion of sulphur is introduced into a stoneware retort or a deep crucible. A mixture of silver, copper, and lead is heated in another crucible, and when melted is poured into the fused sulphur, which transforms these metals into sulphides. A small portion of sal ammoniac is then added, and, after being removed from the crucible or retort, the product is pulverized and is then ready for use.

The proportions generally used are as follows:—

	Parts.			
Silver	8	2	1	1
Copper	18	5	6	2
Lead	13	7	10	4
Sulphur	96	24	36	5

The firm of Zachers, of Berlin, claim to have discovered the process of making the niel called Tula, after the Russian town of the same name. According to them, the niel is prepared from silver 9 parts, copper 1, lead 1, and bismuth 1. The metals are fused and saturated with sulphur. This mixture gives the splendid blue which was formerly erroneously considered as steel blue.

The article to be nielled having been prepared with the graver, by etching or stamping, is then covered—hollows and reliefs, with

16

the pulverized nielling composition made into a stiff paste with solution of sal ammoniac. The article is next heated in the muffle until the composition melts, when it will be found to adhere firmly to the metal. The design is brought out in very effective contrast by denuding the portions in relief, without touching the hollows, which retain a fine black.

To imitate niel by electro-deposition, the design is executed upon the surface with a pigment consisting of white lead and glue or gum-water. The portions which are to remain free are coated with "stopping-off" varnish, and the design is uncovered by etching with very dilute nitric acid. The article is then brought as the anode into dilute solution of ammonium sulphide, while a small sheet of platinum connected to the negative pole is dipped into the solution. Sulphide of silver being formed, the design becomes quickly black-gray, and, after removing the "stopping-off" varnish with benzine, stands out in sharp contrast from the white silver.

Old (antique) silvering.—To give silvered articles an antique appearance coat them with a thin paste of 6 parts graphite, 1 red ochre, and sufficient spirits of turpentine. After drying, a gentle rubbing with a soft brush removes the excess of powder, and the reliefs are set off (discharged) by means of a rag dipped into alcohol.

A tone resembling antique silvering is also obtained by brushing the silvered articles with a soft brush moistened with very dilute alcoholic solution of chloride of platinum.

In order to impart the old silver tinge to small articles, such as buttons, rings, etc., they are agitated in the above mentioned paste, and then "tumbled" with a large quantity of dry sawdust until the desired shade is obtained.

Many operators, at the present day, produce the antique silvering by beginning with the oxidizing process about to be described, and setting off the reliefs by means of a hard brush and pumicestone, or Spanish white. This last process is almost exclusively used for metallic mountings of books and albums.

Oxidized silver.—This term is incorrect, as by it is understood not an oxidation, but a combination with sulphur or chlorine. Solution of pentasulphide of potassium (liver of sulphur of the

shops) is generally used for the purpose. Immerse the articles in a solution of 2.75 drachms of liver of sulphur and $5\frac{1}{2}$ drachms of ammonium carbonate in 1 quart of water heated to 176° F., and allow them to remain until they have acquired the desired dark tone. Immediately after immersion the articles become pale gray, then darker, and, finally, deep black-blue. For coloring in this manner the silvering should not be too thin; for articles with a very thick deposit of silver, solution of double the strength may be used. Very slightly silvered articles cannot be oxidized in this manner, as the bath would remove the silvering, or under the most favorable circumstances produce only a gray color. If the operation is not successful, and the articles come from the bath stained or otherwise defective, dip them in a warm potassium cyanide solution which rapidly dissolves the silver sulphide formed.

A *yellow color* is imparted to silvered articles by immersion in a hot concentrated solution of chloride of copper, rinsing and drying.

Stripping silvered articles.—When a silvering operation has failed, or the silver is to be stripped from old silvered articles, different methods have to be used according to the nature of the basis-metal. Silvered *iron articles* are treated as the anode in potassium cyanide solution in water (1 : 20), the iron not being brought into solution by potassium cyanide. As cathode suspend in the solution a few silver anodes or a copper sheet rubbed with an oily rag; the silver precipitates upon the copper sheet, but does not adhere to it. Articles, the basis of which is *copper*, are best stripped by immersion in a mixture of equal parts of anhydrous (fuming) sulphuric acid and nitric acid of 40° Bé. This mixture makes the copper passive, it not being attacked while the silver is dissolved. Care must, however, be had not to introduce any water into the acids, nor to let them stand without being hermetically closed, since by absorbing moisture from the air they become dilute and may then exert a dissolving effect upon the copper. The fuming sulphuric acid may also be heated in a shallow pan of enamelled cast-iron to between 300° and 400° F. Then at the moment of using it, pinches of dry and pulverized nitrate of potassium (saltpetre) are thrown into it, and the article, held with

copper tongs, is plunged into the liquid. The silver is rapidly removed, while the copper or its alloys is but slightly corroded. According to the rapidity of the solution, fresh additions of saltpetre are made. All the silver has been dissolved when, after rinsing in water and dipping the articles into the cleansing acids, they present no brown or black spots, that is to say, when they behave like new. In this hot acid stripping proceeds more quickly than in the cold acid mixture, but the latter acts more uniformly.

Determination of electro-deposited silvering.—By applying a drop of nitric acid of 1.2 specific gravity, in which red chromate of potash has been dissolved to saturation, to genuine silvering a red stain of chromate of silver is formed. According to Gräger, this method may also be used, to a certain extent, for the recognition of other white metals which may be mistaken for silver. A drop of the mixture applied to *German silver* becomes brown, no red stain appearing after rinsing with water; upon *Britannia* the drop produces a black stain; *zinc* is etched without a colored spot remaining behind; upon *amalgamated* metals a brownish precipitate is formed, which does not adhere and is washed away by water; upon *tin* the drop also acquires a brownish color, and by diluting with water a yellow precipitate is formed; upon *lead* a beautiful yellow precipitate is formed.

Custom-house officers in Germany are directed by law to use the following process for the determination of genuine silvering: Wash a place on the article with ether or alcohol, dry with blotting paper and apply to the spot thus cleansed a drop of a 1 to 2 per cent. solution of crystallized bisulphide of soda prepared by boiling 1.05 ozs. of sodium sulphite and 2.36 drachms of flowers of sulphur with 0.88 oz. of water until the sulphur is dissolved, and diluting to 1 quart of fluid. Allow the drop to remain about ten minutes upon the article and then rinse off with water. Upon silver articles a full, round, steel-gray spot is produced. Other white metals and alloys, with the exception of amalgamated copper, do not show this phenomenon, there appearing at the utmost a dark ring at the edge of the drop. Amalgamated copper is more quickly colored and acquires a more dead black color than silver.

Recovery of silver from old silver baths, etc.—Old solutions which contain silver in the form of a silver salt are easily treated. It is sufficient to add to them, in excess, a solution of common salt, or hydrochloric acid, when all the silver will be precipitated in the state of chloride of silver, which, after washing, may be employed for the preparation of new baths.

For the recovery of silver from solutions which contain it as cyanide, the solutions may be evaporated to dryness, the residue mixed with a small quantity of calcined soda and potassium cyanide, and fused in a crucible, whereby metallic silver is formed, which, when the heat is sufficiently increased, will be found as a button upon the bottom of the crucible; or if it is not desirable to heat to the melting-point of silver, the fritted mass is dissolved in hot water, and the solution containing the soda and cyanide quickly filtered off from the metallic silver. The evaporation of large quantities of fluid, to be sure, is inconvenient, and requires considerable time. But the reducing process above described is without doubt the most simple and least injurious.

According to the *wet method* the bath is strongly acidulated with hydrochloric acid, provision being made for the effectual carrying off of the hydrocyanic acid liberated. Remove the precipitated chloride of silver and cyanide of copper by filtration, and, after thorough washing, transfer it to a porcelain dish and treat it, with the aid of heat, with hot hydrochloric acid, which will dissolve the cyanide of copper. The resulting chloride of silver is then reduced to the metallic state by mixing it with four times its weight of crystallized carbonate of soda and half its weight of pulverized charcoal. The whole is made into a homogeneous paste, which is thoroughly dried, and then introduced into a strongly heated crucible. When all the material has been introduced the heat is raised to promote complete fusion and to facilitate the collection of the separate globules of silver into a single button at the bottom of the crucible, where it will be found after cooling. If granulated silver is wanted, pour the metal in a thin stream and from a certain height into a large volume of water.

Still simpler is the reduction of the chloride of silver by pure zinc; for this purpose suspend the chloride of silver in water,

add hydrochloric acid, and place pure zinc rods or granulated zinc in the fluid. The zinc dissolving, metallic silver is separated, which is filtered off, washed, and dried.

To precipitate the silver from silver solutions containing potassium cyanide it suffices to place a bright sheet of zinc in the solution, though the simultaneous use of a sheet of zinc and a sheet of iron is more suitable. While with the use of zinc alone the silver sometimes adheres firmly to the zinc, it always separates in a pulverulent form when zinc and iron are employed. It is only necessary to wash the separated silver, which, as a rule, contains copper, and after drying to dissolve it, best in warm concentrated sulphuric acid. The solution is diluted with water and the dissolved silver precipitated by means of strips of copper. The silver thus obtained is perfectly pure. If the content of copper is small, it may be removed from the silver precipitated with zinc by fusing with a small quantity of saltpetre and borax.

CHAPTER X.

DEPOSITION OF GOLD.

GOLD is chiefly found in the metallic state, and generally alloyed with more or less silver, copper, and iron. The following analyses will serve to show the general composition of the native metal :—

	Australia.	California.	Russia.	Wales.
Gold	94.64	89.10	98.96	89.83
Silver	4.95	10.50	0.16	9.24
Copper	...	...	0.05	...
Iron	0.41	0.20	0.35	...
	100.00	99.80	99.52	99.07

Gold is one of the few metals possessing a yellow color; precipitated from its solution with green vitriol or oxalic acid, it appears as a brown powder without lustre, which on pressing with the burnisher acquires the color and lustre of fused gold. Pure gold is nearly as soft as lead, but possesses considerable tenacity. In order to increase its hardness when used for articles

of jewelry and for coinage it is mixed with silver or copper. The "fineness of gold," or its proportion in the alloy, is usually expressed by stating the number of carats present in 24 carats of the mixture. Pure gold is stated to be 24 carats "fine;" standard gold is 22 carats "fine;" 18 carat gold is a mixture of 18 parts of gold and 6 of alloy. Gold is the most malleable and ductile of the metals; it may be beaten out into leaves not exceeding $\frac{1}{10,000}$th of a millimeter in thickness. When beaten out into thin leaves and viewed by transmitted light gold appears green; when very finely divided it is dark red or black. The specific gravity of fused gold is 19.35, and of precipitated gold powder from 19.8 to 20.2. Pure gold melts at about 2016° F., and in fusing exhibits a sea-green color. The melting-points of alloyed gold vary according to the degree of fineness. Thus, 23 carat gold melts at 2012° F.; 22 carat at 2009°; 20 carat at 2002°; 18 carat at 1995°; 15 carat at 1992°; 13 carat at 1990°; 12 carat at 1987°; 10 carat at 1982°; 9 carat at 1979°; 8 carat at 1973°; 7 carat at 1960°. The fineness of gold may be approximately estimated by means of the *touch-stone*, a balsatic stone formerly obtained from Asia Minor, but now procured from Saxony and Bohemia. The sample of gold to be tested is drawn across the stone, and the streak of metal is treated with dilute nitric acid; from the rapidity of the action and the intensity of the green color produced—due to the solution of the copper—as compared with streaks made by alloys of known composition, the assayer is enabled to judge of the proportion of inferior metal which is present. Gold preserves its lustre in the air and is not acted upon by any of the ordinary acids. Nitric, hydrochloric, or sulphuric acid by itself does not dissolve gold, but it dissolves in acid mixtures which develop chlorine, hence in aqua regia (nitrohydrochloric acid).

Gold baths.—Electro-gilding may be done with the aid of heat or in the cold, large objects being generally gilded in the cold bath, and smaller objects in the hot bath. The latter has the advantage of requiring less current-strength, besides yielding deposits of greater density and uniformity and of sadder, richer tones. Baths for hot gilding work with a moderate content of gold—11½ to 12½ grains of gold per quart—while baths for cold gilding should contain not less than 54 grains per quart.

Some authors—for instance, Elsner, Briant, Selm, and others—give the preference to baths prepared with potassium ferrocyanide; while others, like Elkington and Regnault, work with a solution of gold-salt and potassium bicarbonate; and Böttcher, Leuchtenberg, and others recommend a solution of cyanide of gold in potassium cyanide. With proper treatment of the bath, good results may be obtained with either. However, the use of baths prepared with potassium ferrocyanide cannot be recommended on account of the secondary decompositions which take place during the operation of plating, and because the baths do not dissolve the gold anodes. In the following, only approved formulæ for the preparation of gold baths will be given:—

I. *Bath for cold gilding.*—Fine gold in the form of fulminating gold 54 grains, 98 per cent. potassium cyanide 0.35 to 0.5 oz. (according to the current-tension used), water 1 quart.

To prepare this bath, dissolve 54 grains of fine gold in aqua regia in a porcelain dish heated over a gas or alcohol flame, and evaporate the solution to dryness. Continue the heating until the solution is thickly fluid and dark brown and on cooling congeals to a dark brown, foliated mass. Heating too strongly should be avoided, as this would cause decomposition and the auric chloride would be converted into aurous chloride, and eventually into metallic gold and escaping chlorine. The neutral chloride of gold prepared in this manner is dissolved in 1 pint of water and aqua ammonia added to the solution as long as a yellow-brown precipitate is formed, avoiding, however, a considerable excess of aqua ammonia. The precipitate of fulminating gold is filtered off, washed, and dissolved in 1 quart of water containing 0.5 oz. of potassium cyanide in solution. The solution is boiled, replacing the water lost by evaporation, until the odor of ammonia which is liberated by dissolving the fulminating gold in potassium cyanide disappears when it is filtered. Instead of dissolving the gold and preparing neutral chloride of gold by evaporating, it is more convenient to use 108 grains of chemically pure neutral chloride of gold as furnished by chemical works, and precipitate the fulminating gold from its solution.

Too large an excess of potassium cyanide yields gold deposits of an ugly, pale color. When working with a more powerful

current, the excess of potassium cyanide need only be slight; with a weaker current it must be larger. With 10 per cent. excess of free potassium cyanide, the most suitable current-strength is 3 volts.

The fulminating gold should not be dried, as in this condition it is highly explosive, but should be immediately dissolved while in a moist state.

For cold gilding, Roseleur recommends the following bath: II. Fine gold as neutral chloride of gold 0.35 oz., 98 per cent. potassium cyanide 0.7 oz., water 1 quart.

Dissolve the gold-salt from 0.35 oz. of fine gold or about 0.7 oz. of neutral chloride of gold in $\frac{1}{2}$ pint of water, and the potassium cyanide in $1\frac{1}{2}$ pints of water, and after mixing the solutions boil for half an hour. The preparation of this bath is more simple than that of formula I., but the color of the gold deposit obtained with the latter is warmer and sadder than with the first. The high content of gold in the bath, prepared according to formula II., readily causes a red-brown gold deposit, and hence special attention has to be paid to the regulation of the current.

For those who prefer gold baths prepared with yellow prussiate of potash instead of potassium cyanide, the following formula for *cold gilding* is given:—

III. Yellow prussiate of potash (potassium ferrocyanide) 0.5 oz., carbonate of soda 0.5 oz., fine gold (as chloride of gold or fulminating gold) 30.75 grains, water 1 quart.

To prepare the bath, heat the solutions of the yellow prussiate of potash and of the carbonate of soda in the water to the boiling-point, add the gold-salt, and boil $\frac{1}{4}$ hour, or with the use of freshly precipitated fulminating gold, until the odor of ammonia disappears. After cooling, the solution is mixed with a quantity of distilled water corresponding to the water lost by evaporation, and filtered. This bath gives a beautiful bright gilding upon all metals, even upon iron and steel. Suitable current-strength 3.25 to 3.26 volts.

Gold bath for hot gilding.—IV. Fine gold (as fulminating gold) 15.4 grains, 98 per cent. potassium cyanide 77 grains, water 1 quart.

This bath is prepared in the same manner as that according to

formula I., from 15.4 grains of fine gold, which is converted into neutral chloride of gold by dissolving in aqua regia and evaporating; or dissolve directly 29.32 to 30.75 grains of chemically pure neutral chloride of gold in water, precipitate the gold as fulminating gold with aqua ammonia, wash the precipitate, dissolve it in water containing the potassium cyanide, and heat until the odor of ammonia disappears, replacing the water lost by evaporation. This bath yields a beautiful sad gilding of great warmth. All that has been said in regard to the content of potassium cyanide in the bath prepared according to formula I. also applies to this bath. The temperature should be between 158° and 176° F., and the current-strength 2.0 to 2.5 volts.

Roseleur recommends for hot gilding: V. Chemically pure crystallized sodium phosphate 2.11 ozs., neutral sodium sulphide 0.35 oz., potassium cyanide 30.86 grains, fine gold (as chloride) 15.43 grains, distilled water 1 quart.

If this bath is to serve for the direct gilding of *steel*, only 15.43 instead of 30.86 grains of potassium cyanide are to be used. Dissolve in a porcelain dish, with the aid of moderate heat, the sodium phosphate and sodium sulphide, and when the solution is *cold*, add the neutral chloride of gold prepared from 15.43 grains of gold = about 30.86 grains of commercial chloride of gold, and the potassium cyanide; for use, heat the bath to between 158° and 167° F.

Conrad Taucher recommends the following formulæ for hot gilding:—

VI. Sodium phosphate 14 ozs., sodium bisulphite $3\frac{1}{2}$ ozs., sodium bicarbonate $1\frac{3}{4}$ ozs., caustic potash $1\frac{3}{4}$ ozs., potassium cyanide 14 drachms, gold in the form of neutral chloride $8\frac{1}{2}$ drachms, distilled water 10 quarts.

With the exception of the chloride of gold all the salts may be dissolved together. The solution, if necessary, is filtered and the gold solution added. The bath is used at between 122° and 140° F. It yields a very beautiful gilding, but requires a quite strong current for its decomposition. It is not suitable for the direct gilding of steel.

VII. Yellow prussiate of potash (potassium ferrocyanide) $5\frac{1}{4}$

ozs., pure potassium carbonate $1\frac{3}{4}$ ozs., sal ammoniac $11\frac{1}{4}$ drachms, gold in the form of neutral chloride $5\frac{1}{2}$ drachms, water 5 quarts.

Dissolve with the assistance of heat the first three salts, filter, and when cold add the chloride of gold. Then heat again and boil for half an hour, replacing the water lost by evaporation.

Many electro-platers prepare the gold baths with the assistance of the electric current. For this purpose prepare a solution of 3.52 ozs. of potassium cyanide (98 to 99 per cent.) per quart of water, and after heating to between 122° and 140° F. conduct the current of two Bunsen elements through two sheets of gold, not too small, which are suspended as electrodes in the potassium cyanide solution. The action of the current is interrupted when the solution is so far saturated with gold that an article immersed in it and connected to the negative pole in place of the other gold sheet is gilded with a beautiful warm tone. By weighing the sheet of gold serving as anode, the amount of gold which has passed into the solution is ascertained. According to English authorities, a good gold bath prepared according to this method should contain 3.52 ozs. of potassium cyanide and 0.7 oz. of fine gold per quart of water.

The only advantage of this mode of preparing the bath is that it excludes a possible loss of gold which may occur in dissolving gold, evaporating the gold solution, etc., by breaking the vessel containing the solution. However, by using commercial chemically pure chloride of gold such loss is avoided, and the bath prepared according to the formulæ given yields richer tones than a gold bath produced by electrolysis. Besides, the preparation of the gold bath with the assistance of the electric current can only be considered for smaller baths, since the saturation of a larger volume of potassium cyanide solution requires considerable time, and the potassium cyanide is strongly decomposed by long heating.

Management of gold baths.—It is advisable to keep the content of gold in the baths prepared according to the different formulæ as constant as possible, which is best effected by the use of fine gold anodes. Insoluble platinum anodes are more liked in gilding than for all other electro-plating processes, partly because they are cheaper, and partly because they are recommended in most books on the subject. However, a bath which has become

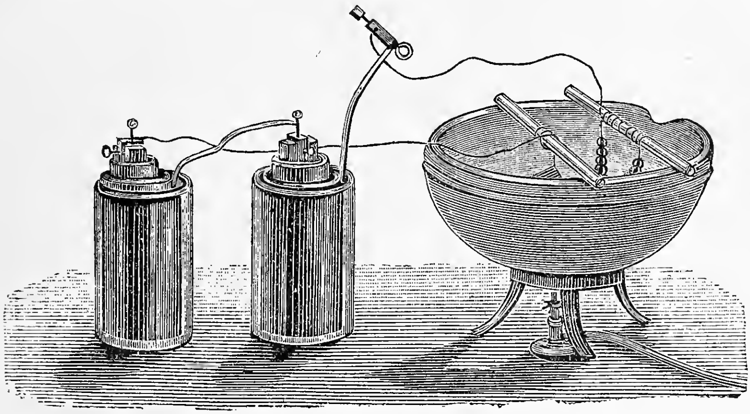
low in gold does not yield a beautiful gold color, and has to be frequently strengthened by the addition of chloride of gold, the preparation of which consumes time and causes expense, so that the use of gold anodes is the cheapest in the end. The employment of anodes of platinum strips or platinum wire may, perhaps, be advocated for coloring the deposit, *i. e.*, for the purpose of obtaining certain tones of color when gilding in the hot bath. By allowing the platinum anode to dip only slightly in the bath a pale gilding is obtained, because the current thereby becomes weaker; by immersing the anode deeper the color becomes more yellow, and by immersing it entirely the tone becomes more reddish. However, instead of producing these effects of the current-strength by the anode, which requires the constant presence of the operator, it is better to obtain the coloration by means of the resistance board. By placing the handle upon "strong" a reddish gold tone is obtained, and by placing it upon "weak" a paler gold tone, while the beautiful gold yellow lies in the middle between the two extremes. However, since even with the use of gold anodes the content of gold in the bath is not entirely restored, the bath has after some time to be strengthened, which is effected by a solution of fulminating gold or chloride of gold in potassium cyanide, according to the composition of the bath.

As in the silvering baths, the excess of potassium cyanide in the gold baths is also partially converted into potassium carbonate by the action of the air, the heat, etc., and it is, therefore, advisable from time to time to add a small quantity of potassium cyanide.

Gold baths for cold gilding are kept in vats of stoneware or enamelled iron, or small baths, in glass vats, which, to protect them against breaking, are placed in a wooden box. Baths for hot gilding require enamelled iron vats in which they can be heated by a direct fire, or better, by placing in hot water (water bath), or by steam. For small gold baths for hot gilding, a porcelain dish resting upon a short-legged iron tripod may be used. (Fig. 114.) Beneath the iron tripod is a gas burner supplied with gas by means of flexible India-rubber tubing connected to an ordinary gas burner. Across the porcelain dish are placed two glass rods around which the pole-wires are wrapped.

In heating larger baths in enamelled vats over a direct fire it may happen that on the places most exposed to the heat the enamel may blister and peel off; it is, therefore, better to heat the baths in a water or steam bath. For this purpose have made a box of

Fig. 114.



stout iron or zinc sheet and about $\frac{3}{4}$ inch wider and longer, and about 4 inches deeper than the enamelled vat containing the gold bath. To keep the level of the water constant the box is to be provided with a water inlet and overflow pipe. In this box place the vat so that its edges rest upon those of the box and make the joints tight with tow. The water-bath is then heated over a gas flame or upon a hearth, the water lost by evaporation being constantly replaced, so that the enamelled vat is always to half its height surrounded by hot water. For heating by steam the arrangement is the same, only a valve for the introduction and a pipe for the discharge of steam are substituted for the water inlet and overflow pipe.

Execution of gilding.—Like all other electro-plating operations, it is advisable to execute gilding with an external source of current; that is, to use a battery or other source of current separated from the bath, and to couple the apparatuses as previously described and illustrated by Figs. 47 and 50.

To be sure, there are still gilders who gild without a battery or separate external source of current and obtain good results, the

process being, as a rule, employed only in gilding small articles. The apparatus used for this purpose consists of a glass vessel containing the gold solution compounded with a large excess of potassium cyanide and a porous clay cell filled with very dilute sulphuric acid or common salt solution, which is placed in the glass vessel; care should be taken to have the fluids in both vessels at the same level. Immerse in the clay cell an amalgamated zinc cylinder or zinc plate, to which a copper wire is soldered. Outside the cell this copper wire is bent downwards, and the article to be gilded, which dips in the gold solution, is fastened to it. In working with this apparatus there is always a loss of gold, since the gold solution penetrates through the porous cell, and on coming in contact with the zinc is reduced by it, the gold being separated as black powder upon the zinc. In cleaning the apparatus this black slime has to be carefully collected and worked for fine gold.

For the sake of greater solidity, only articles of silver and copper and its alloys should be directly gilded, while all other metals are best first brassed or coppered. Cleaning from grease and pickling is done in the same manner, as described on page 131. The preparation of the articles for gilding differs from that for silvering only in that the surfaces which later on are to appear with high lustre are not artificially roughened with emery, pumice, or by pickling, because, on the one hand, the gold deposit seldom needs to be made extravagantly heavy, and the rough surface formed would require more laborious polishing with the burnishers; and, on the other, the gold deposits adhere quite well to highly-polished surfaces provided the current-strength is correctly regulated, and the bath accurately composed according to one of the formulæ given. Quicking the articles before gilding, which is recommended by some authors, is not necessary.

The current-strength must, under no circumstances, be so great that a decomposition of water and consequent evolution of hydrogen on the objects take place, since otherwise the gold would not deposit in a reguline and coherent form, but as a brown powder. By regulating the current-strength so that it just suffices for the decomposition of the bath, and avoiding a considerable surplus, a very dense and uniform deposit is formed; and by allowing the

object to remain long enough in the bath, a beautiful, dull gold deposit can be obtained in all the baths prepared according to the formulæ given. It may, however, be mentioned that this mode of dull gilding is the most expensive, since it requires a very heavy deposit, and it will, therefore, be better to deaden the surface previous to gilding according to a process to be described later on.

For gilding with cold baths two freshly filled Bunsen elements coupled for tension suffice in almost all cases, while for hot baths one element is, as a rule, sufficient, if the anode surface is not too small. The more electro-positive the metal to be gilded is, the weaker the current can and must be.

Though gold solutions are good conductors and, therefore, the portions which do not hang directly opposite the anodes gild well, for the solid gilding of larger objects it is recommended to frequently change their positions except when they are entirely surrounded by anodes.

The inner surfaces of *hollow-ware*, such as drinking-cups, milk pitchers, etc., are best gilded after freeing them from grease and pickling, by filling the vessel with the gold bath and suspending a current-carrying gold anode in the centre of the vessel, while the outer surface of the latter is brought in contact with the negative conducting wire. The lips of vessels are gilded by placing upon them a cloth rag saturated with the gold bath and covering the rag with the gold anode.

For gilding in the cold bath the process is as follows: The objects, thoroughly freed from grease and pickled (and if of iron, zinc, tin, Britannia, etc, previously coppered), are hung in the bath by copper wires, where they remain with a weak current until in about 8 or 10 minutes they appear uniformly gilded. At this stage they are taken from the bath, rinsed in a pot filled with water, which, after working for some time, is added to the bath to replace the water lost by evaporation, and brushed with a fine brass scratch-brush and tartar solution. They are then thoroughly rinsed, again freed from grease by brushing with lime-paste and then returned to the bath, where they remain until they have acquired a deposit of sufficient thickness.

If it is intended to give them a very heavy deposit, it is advis-

able to scratch-brush them several times with the use of tartar or its solution. For gilding by weight the same plan as given for silvering (p. 223) is pursued.

For gilding with the hot bath the operations are the same, with the exception that a weaker current is introduced into the bath and the time of the gilding process shortened. Frequent scratch-brushing also increases the solidity of the deposit and prevents the premature turning to a dead brown-black. Since in hot gilding more gold than intended is readily deposited, it is especially advisable to place a resistance board in the circuit, as otherwise the operator must remain standing on the bath and regulate the effect of the current by immersing the anodes more or less.

With a somewhat considerable excess of potassium cyanide, and if the objects to be gilded are not rapidly brought in contact with the current carrying object rod, hot gold baths cause the solution of some metal. Therefore, when silver or silvered objects are constantly gilded in them they yield a somewhat greenish gilding in consequence of the absorption of silver, or a reddish gilding due to the absorption of copper, if copper or coppered articles are constantly gilded in them. Hence, for the production of such green or reddish color, gilding baths which have thus become argentiferous or cupriferons may be advantageously used. In order to obtain a deposit of green or red gold with fresh baths, the tone-giving addition of metal must be artificially effected, as will immediately be seen.

If, however, such extreme tones are not desired, the content of gold in the baths may be exhausted for preliminary gilding with the use of platinum anodes, the sad gold color being then given in a freshly prepared bath.

The gold deposits are polished, in the same manner as silver deposits, with the burnisher and red ochre, and moistening with solution of soap, decoction of flaxseed, or soap-root, etc.

Red gilding.—In order to obtain a red gold with the formulæ given, a certain addition of cyanide of copper dissolved in potassium cyanide has to be made to them. The quantity of such addition cannot be well expressed by figures, since the current-strength with which the articles are gilded exerts considerable influence. It is best to triturate the cyanide of copper in a

mortar to a paste with water, and add of this paste to a moderately concentrated potassium cyanide solution as long as cyanide of copper is dissolved. Of this copper solution add, gradually and in not too large portions, to the gold solution until, with the current-strength used, the gold deposit shows the desired red tone. The absorption of copper by the bath may also be effected by replacing the gold anodes by copper anodes and circulating the current (suspending a few gold anodes to the object rod). The direct addition of cyanide of copper is, however, preferable.

For the determination of the content of copper required for the purpose of obtaining a beautiful red gold, a bath for hot gilding which contained 10.8 grains of gold per quart was compounded with a solution of cyanide of copper in potassium cyanide with 1.08 grains content of copper. The tone of the gilding, which previously was pure yellow, immediately passed into a pale red gold. By the further addition of 1.08 grains of copper a fiery red gold tone was obtained, while a third addition of 1.08 grains of copper yielded a color more approaching that of copper than of gold. These experiments show that 20 per cent. of copper of the weight of gold contained in the bath seems to be the most suitable proportion for obtaining a beautiful red gold.

Green gilding.—To obtain a greenish gilding, solution of cyanide or chloride of silver in potassium cyanide has to be added to the gold bath. It is not easy to prepare greenish gilding of a pleasing color, and to obtain it the current-strength must be accurately proportioned to the object-surface, since with too weak a current silver predominates in the deposit, the gilding then turning out whitish, while too strong a current deposits too much gold in proportion to silver, the gilding becoming yellow, but not green.

Rose-color gilding may be obtained by the addition of suitable quantities of copper and silver solution, but such coloration, like those previously mentioned, requires much attention and reflection. Hot gold baths are most suitable for such colorations.

Dead gilding.—As previously mentioned, a beautiful dead gold-deposit may be obtained by the use of any of the formulæ given and a correctly regulated current, and allowing sufficient length of time for gilding; but the heavy deposit of gold required

for this process makes it too expensive, and it is therefore advisable to produce dead gilding without excessively heavy deposits by previous deadening of the basis-surface. The process of graining has already been described on p. 237 ; *another method* is to deaden the first thin deposit of gold with the deadening scratch-brush, and then to give a second deposit of gold, which also turns out dead upon the deadened surface. However, this operation of deadening with the scratch-brush requires considerable skill, and it is therefore best to deaden the surface according to one of the following methods :—

For this purpose, the mixture of 1 volume of saturated solution of bichromate of potash, and 2 volumes of concentrated hydrochloric acid, mentioned on p. 131, may be used. Brass articles are allowed to remain in the mixture several hours, and are then quickly drawn through the bright-dipping bath ;

Or, by depositing upon the articles a coating of frosted silver and then gilding in a good gold bath. Unfortunately, this method is somewhat expensive, and the burnished parts are greenish. Moreover, the intermediary coat of silver is easily affected by sulphurous gases, the gilding being thereby blackened.

More advantageous is the process of providing the articles with a dead copper coating in the acid galvanoplastic copper bath, then quicking them, and finally gilding. This gilding is very handsome in lustre and color.

Dead gilding on zinc.—By the following process of depositing gold on zinc, effects similar to those of fire-gilding on bronze are produced. The zinc is first heavily coppered in one of the copper baths previously given, and is then brought into a silvering bath (with use of a battery) or into an acid copper bath (see "Galvanoplasty"), according to whether deadening is to be effected with silver or copper. In deadening in the acid copper bath care should be taken that the suspending wires are in contact with the object-rod before immersing the coppered zinc object in the bath. However, this process of coppering zinc in the acid copper bath is a very delicate operation, it being frequently observed that even with an apparently very heavy coppering in the electro-coppering bath, brownish-black spots appear on the objects when brought into the acid bath, the copper being deposited on these

spots in a pulverulent form by the contact of the acid bath with the zinc. If this is observed, the objects have to be immediately taken from the bath, and after thorough scratch-brushing again thoroughly and quickly coppered in the electro-coppering bath before returning them to the acid copper bath. It may be recommended, first to provide the coppered zinc objects with a thin coat of nickel, and then to copper them in the acid copper bath.

When the deposit seems of sufficient thickness, the zinc is washed in a large quantity of water, drawn through a weak solution of mercurous nitrate, and brought into a hot gilding bath composed as follows: Water 10 quarts, sodium phosphate 21 ozs., sodium bisulphite $3\frac{1}{2}$ ozs., potassium cyanide $11\frac{1}{4}$ drachms, gold (in the form of chloride) $5\frac{3}{4}$ drachms.

At first quite a strong current is used, which is gradually reduced up to the moment when the object is taken from the bath.

Coloring of the gilding.—It has been frequently mentioned that the most rational and simple process of giving certain tones of color to the gilding is by means of a stronger or weaker current. Many operators, however, cling to the old method of effecting the coloration by gilder's wax or brushing with certain mixtures, and for this reason this process, which is generally used for coloring fire-gilding, shall be briefly mentioned.

To impart to the gold-deposit a *redder* color, the gilding-wax is prepared with a greater content of copper, while for greenish gilding more zinc-salt is added. There are innumerable receipts for the preparation of gilding-wax, nearly every gilder having his own receipt, which he considers superior to all others. Only two formulæ which yield good results will here be given, one (I.) for *reddish* gilding and one (II.) for greenish gilding.

I. Wax 12 parts by weight, pulverized verdigris 8, pulverized sulphate of zinc 4, copper scales 4, borax 1, pulverized bloodstone 6, copperas 2.

II. Wax 12 parts by weight, pulverized verdigris 4, pulverized sulphate of zinc 8, copper scales 2, borax 1, pulverized bloodstone 6, copperas 2.

Gilder's wax is prepared as follows: Melt the wax in an iron kettle, add to the melted mass, with constant stirring, the other

ingredients, pulverized and intimately mixed, in small portions, and stir until cold, so that the powder cannot settle on the bottom or form lumps. Finally mould the soft mass into sticks about $\frac{1}{3}$ inch in diameter.

The operation for applying the gilder's wax is as follows: Coat the heated gilded articles uniformly with the wax and burn off over a charcoal fire, frequently turning the articles. After the extinguishment of the wax flames plunge the articles into water, scratch-brush with wine-vinegar, dry in sawdust, and polish.

To give gilded articles a beautiful, rich appearance, the following process may also be used: Mix 3 parts by weight of pulverized alum, 6 of saltpetre, 3 of sulphate of zinc, and 3 of common salt, with sufficient water to form a thinly-fluid paste. Apply this paste as uniformly as possible to the articles by means of a brush, and after drying, heat the coating upon an iron plate until it turns black; then wash in water, scratch-brush with wine-vinegar, dry, and polish.

According to a French receipt, the same result is attained by mixing pulverized blue vitriol 3 parts by weight, verdigris 7, sal ammoniac 6, and saltpetre 6, with acetic acid 31; immersing the gilded articles in the mixture or applying the latter with a brush; then heating the objects upon a hot iron plate until they turn black, and, after cooling, pickling in concentrated sulphuric acid.

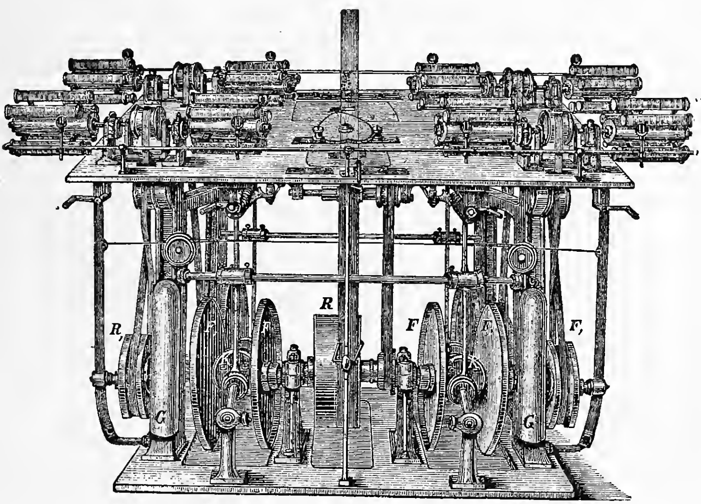
Some gilders *improve bad tones of gilding* by immersing the articles in dilute solution of nitrate of mercury until the gilding appears white; the mercury is then evaporated over a flame and the articles are scratch-brushed. Others apply a paste of pulverized borax and water, heat until the borax melts, and then quickly immerse in dilute sulphuric acid.

Incrustations with gold are produced in the same manner as incrustations with silver described on p. 240.

Gilding of metallic wire and gauze.—Fine wire of gilded copper and brass is much used in the manufacture of metallic fringes and lace, for epaulettes and other purposes. The fine copper and brass wires being drawn through the draw-irons and wound upon spools by special machines, and hence not touched by the hands, freeing from grease may, as a rule, be omitted. The first requisite for

gilding is a good winding machine, which draws the wires through the gold bath and wash boxes, and further effects the winding of the wire upon spools. The principal demand made in the construction of such a machine is that by means of a simple manipulation a great variation in the speed with which the wire or gauze passes through the gold bath can be obtained. This is necessary in order to be able to regulate the thickness of the gilding by the quicker or slower passage of the wire. A machine well adapted for this purpose is that constructed by J. W. Spaeth and shown in Fig. 115.

Fig. 115.



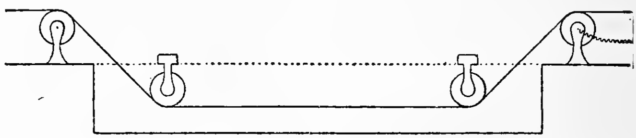
The variation in the passage of the wire is attained by the two friction-pulleys *F*, which sit upon a common shaft with the driving-pulley *R*, and transmit their velocity by means of the friction-pistons *KK'* to the friction-pulley *F'*, which is firmly connected to the belt-pulley *R* driving the spool spindle. Since by a simple device the pistons *K* and *K'* may be shifted, it is clear that the transmission of the number of revolutions from *F* to *F'* is dependent on the position of the friction pistons *K* and *K'*, and that the velocity will be the greater the shorter the distance they are from the centre of the friction-pulleys *F* and *F'*. In order that the friction between *F*, *K*, and *F'* may always be sufficient for the

transmission of the motion, even when the pistons are worn, four weights, *G*, are provided, which press the above-mentioned parts firmly against each other.

In front of each spool of this machine is inserted a small enamelled iron vat which contains the gold bath, and is heated by a gas flame to about 167° F. Between this bath and the winding machine is another small vat with hot water in which the gilded wire is rinsed.

The wires unwind from a reel placed in front of the gold baths, run over a brass drum which is connected to the negative pole of

Fig. 116.



the source of current, and transmits the current to the wires; the dipping of the wires into the gold bath is effected by porcelain drums, which are secured to heavy pieces of lead placed across the vats as shown in Fig. 116. The gilded wire being wound upon the spools of the winding machine, these spools are removed and thoroughly dried in the drying chamber. The wire is then again reeled off on to a simple reel, in doing which it is best to pass it through between two soft pieces of leather to increase its lustre.

The most suitable gold bath is that prepared according to formula IV.; the current-strength should be from 6 to 8 volts, which will produce a deposit of sufficient thickness even with the wire passing at the most rapid rate through the bath.

Gilding by contact, by immersion, and by friction.—For contact gilding by touching with zinc, formulæ I., II., IV., and V., may be used, IV. and V. being especially suitable if the addition of potassium cyanide is somewhat increased and the baths are sufficiently heated.

A contact gold bath prepared with yellow prussiate of potash according to the following formula also yields a good deposit: VIII. Fine gold as chloride of gold 54 grains, yellow prussiate of potash 1 oz., potash 1 oz., common salt 1 oz., water 1 quart. The

bath is prepared as given for formula III.; for use, heat it to boiling.

Gilding by contact is done the same way as silvering by contact. The points of contact must be frequently changed, since in the gold bath intense stains are still more readily formed than in the silver bath.

For gilding by contact, Conrad Taucher recommends the following bath: Distilled water 10 quarts, sodium or potassium pyrophosphate 28 ozs., prussic acid 4½ drachms, crystallized chloride of gold 13½ drachms.

To prepare the bath, bring into a porcelain vessel or into a dish of enamelled cast-iron 9 quarts of distilled* water and add the 28 ozs. of pyrophosphate, stirring constantly with a glass rod. Then heat, and when solution is complete filter and set aside to cool.

While filtering the solution the chloride of gold is prepared by bringing into a small glass flask 5½ drachms of fine rolled gold, 14 drachms of pure hydrochloric acid, and 8½ drachms of pure nitric acid. Apply a gentle heat to the bottom of the flask. In a few seconds vigorous effervescence accompanied by the evolution of orange-red vapors takes place, and the gold in a few minutes dissolves to a reddish-yellow fluid. To evaporate an excess of acids, which if brought into the bath might cause serious disturbances and even render the bath entirely useless, the flask is placed upon a piece of sheet-iron provided in the centre with a hole about 0.11 inch in diameter, and heated upon a stove or over a spirit lamp. When no more vapors escape and the solution has become thickly fluid and has acquired an intense hyacinth-red color, remove the flask by means of wooden pincers from the fire and let cool. If properly prepared, the chloride of gold then congeals to an aggregate of saffron-yellow acicular crystals. If the color of the latter is red, too much heat has been applied. Such chloride of gold is very suitable for the preparation of electro-gilding baths, but if it is to be used for contact gilding a

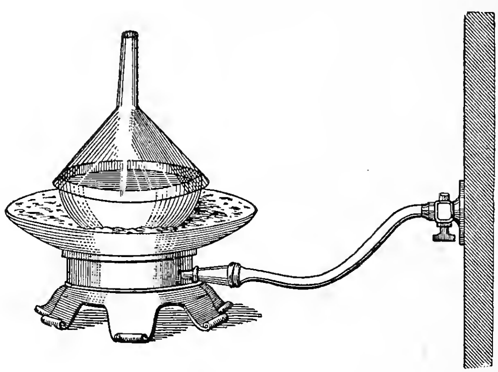
* The use of distilled water is necessary, otherwise the lime salts contained in ordinary water would decompose a portion of the pyrophosphate.

small quantity of the above-mentioned two acids has to be added, and, after heating, the mass has to be again evaporated.

It frequently happens that by careless manipulation the gold is "burnt," *i. e.*, the auric chloride is decomposed by too long, continued heating and is converted into insoluble aurous chloride, or even into pulverulent metallic gold. If such is the case, the treatment with the above-mentioned mixture of acids has to be repeated. The object of the perforated piece of sheet-iron on which the flask is placed for the purpose of evaporating the solution is to prevent the sides of the flask from being heated too strongly, as otherwise the thin layers of chloride of gold solution might be decomposed.

In practice porcelain capsules which are heated in a sand bath are generally used for dissolving gold. Fig. 117 shows such a capsule with glass funnel in a sand bath over a gas stove. The purpose of the glass funnel is to prevent any fluid from being thrown from the capsule at the moment of effervescence caused by the action of the acids upon the metal.

Fig. 117.



The cold crystallized chloride of gold in the flask or the capsule is now dissolved in a small quantity of distilled water, solution being effected almost immediately. The solution is poured upon a filter of filtering paper in a glass funnel placed upon a clean bottle. A small piece of paper should be inserted between the

funnel and the neck of the bottle, so that the air can escape from the latter and the fluid run off from the filter.

The object of filtering is to separate the small quantity of chloride of silver formed from the little silver which is present even in the purest commercial gold. To bring all the gold into the bath repeatedly wash the bottle and the filter with a small quantity of distilled water.

Now mix the cold solution of the pyrophosphate and that of the chloride of gold by pouring the latter gradually into the former and stirring with a glass rod. Then add the $4\frac{1}{2}$ drachms of prussic acid and heat to the boiling-point, when the bath is ready for use.

When mixed cold the bath has a yellow or yellow-greenish color, which disappears as the temperature rises. However, the fluid sometimes becomes currant-red or violet, which indicates that it contains too little prussic acid. This is remedied by adding drop by drop prussic acid until the fluid is entirely discolored. Great care must, however, be exercised in adding the acid, as an excess of it renders the gilding pale.

By following the directions above given, the bath is very suitable for producing a beautiful yellow gilding on objects previously thoroughly cleansed. The articles should be passed through a very weak solution of mercurous nitrate, otherwise the gilding shades and becomes reddish. The articles to be gilded must be constantly moved in the bath; they are suspended to hooks or brought into the bath in dipping baskets of stoneware or brass.

Gilding is finished in a few seconds. The articles are then washed in clean water, dried in dry and warm sawdust, and, if necessary, immediately polished.

By neglecting the precautionary measures given above, the gilding sometimes appears tarnished and dissimilar in tone.. It is then colored or treated with the so-called matt for gilded articles.

For this purpose melt equal parts of the following salts in their water of crystallization at about 212° F.: Ferrous sulphate (green vitriol), zinc sulphate (white vitriol), alum, and saltpetre.

Thoroughly wet every portion of the defective gilding by turning the articles about in this mixture. Then place them in the centre of a cylindrical stove, in which the coal burns between the

sides and a cylindrical grate, so that the entire heat radiates toward the empty space in the centre. The salts melt and then get into a fiery flux, the entire mass acquiring a dull earthen color. When on touching the articles with the moistened finger a slight hissing noise is heard, the temperature is sufficiently high and the articles are thrown into weak starch water acidulated with sulphuric acid. The coating of salts dissolves immediately and the gilding presents a beautiful warm and uniform appearance. This operation can, of course, only be executed if the entire article has been gilded.

For baths for gilding by dipping the following two formulæ have stood the test: I. Crystallized sodium pyrophosphate 2.82 ozs., 12 per cent. prussic acid 4.51 drachms, crystallized chloride of gold 1.12 drachms, water 1 quart. Heat the bath to the boiling-point, and immerse the pickled objects of copper or its alloys, moving them constantly until gilded. Iron, steel, tin, and zinc should previously be coppered ; coating the objects with mercury (quicking) before immersion being entirely superfluous.

All gold baths prepared with sodium pyrophosphate give rapid and beautiful results when fresh, but they have the disadvantage of quickly decomposing, and consequently can seldom be completely exhausted. In this respect the following formula answers much better:—

II. Crystallized sodium phosphate 2.82 drachms, chemically pure caustic potash 1.69 drachms, chloride of gold 0.56 drachm, 98 per cent. potassium cyanide 9.03 drachms, water 1 quart. Dissolve the sodium phosphate and caustic potash in $\frac{3}{4}$ of the water, and the potassium cyanide and chloride of gold in the remaining $\frac{1}{4}$. Heat the solution to the boiling-point. The bath can be almost entirely exhausted, it not being decomposed by keeping. Should the bath become weak, add about 2.82 drachms of potassium cyanide, and use it for preliminary dipping until no more gold is reduced. To complete the coating, the objects subjected to such preliminary dipping are then immersed for a few seconds in a freshly prepared bath of the composition given above.

The layer of gold formed is in all cases very thin, the amount of gold deposited corresponding to the quantity of basis-metal which has been dissolved.

III. One of the best directions for gilding without the use of a current is, according to the "Edelmetallindustrie," as follows: Prepare a solution of gold in aqua regia (2 parts hydrochloric acid and 1 part nitric acid). The solution of the gold is effected in a porcelain dish, best in a sand or water bath, whereby heavy brown acid vapors of hyponitrous acid are evolved. When all is dissolved allow the acid to evaporate until the fluid has acquired a deep brown color and no more acid vapors arise. Then, after cooling, dilute the solution with water and keep it in a bottle for future use. Next dissolve in the bath $6\frac{3}{4}$ drachms of potassa and $11\frac{1}{4}$ drachms of sodium phosphate, and add enough gold solution that the bath contains about $2\frac{1}{4}$ drachms of gold. To this bath, containing about 8 to 10 quarts of fluid, add carefully, with constant stirring, $1\frac{3}{4}$ ozs. of potassium cyanide, and then let it thoroughly boil for some time. After cooling the bath to about 176° or 158° F., suspend the articles in it and keep the bath at this temperature. The bath only requires an occasional addition of gold solution (when the gilding becomes gray or dirty), or of potassium cyanide (when the gilding becomes foxy), and, with proper treatment, can be used for a long time.

Gilding of porcelain, glass, etc.—The pyrophosphate baths given above may be advantageously employed for gilding porcelain, glass, stoneware, etc. the process being as follows:—

Neutral platinic chloride is intimately triturated with enough lavender oil to form a thin syrup. Of this preparation a scarcely perceptible film is applied by means of a small brush to the article to be ornamented. When dry, the article is heated in a muffle to a dark red heat. At this temperature the essential oil partially volatilizes, while another portion is decomposed, and reduces by its hydrogen the platinic chloride to metallic platinum, the result being a coating of metal of a finely polished appearance. When cold the article is immediately drawn through nitric acid, which does not attack the platinum, but removes any impurities which might make its surface dull. The article is then washed in a large quantity of water, wrapped with fine brass wire in such a manner that the wire touches the platinized places at many points, and is then brought into the gold bath. In a few minutes

the platinum is coated with a beautiful smooth film of gold, which adheres well, and only requires rubbing with chamois.

By this method the expensive work of polishing is rendered unnecessary, which with articles having many depressed places is besides almost impossible. If the gilding is too red, add to the bath a few drops of the double cyanide of potassium and silver.

Gilding by friction.—This process is variously termed *gilding with the rag, with the thumb, with the cork.* It is chiefly employed upon silver, though sometimes also upon brass and copper. The operation is as follows: Dissolve 1.12 to 1.69 drachms of chloride of gold in as little water as possible, to which has previously been added 0.56 drachm of saltpetre. Dip in this solution small linen rags, and, after allowing them to drain off, dry them in a dark place. These rags saturated with gold solution are then charred to tinder at not too great a heat, whereby the chloride of gold is reduced, partially to protochloride and partially to finely divided metallic gold. This tinder is then rubbed in a porcelain mortar to a fine uniform powder.

To gild with this powder, dip into it a charred cork moistened with vinegar or salt water and rub, with not too gentle a pressure, the surface of the article to be gilded, which must be previously cleansed from adhering grease. The thumb of the hand may be used in place of the cork, but in both cases care must be had not to moisten it too much, as otherwise the powder takes badly. After gilding the surface may be carefully burnished.

For gilding by friction a solution of chloride of gold in an excess of potassium cyanide may also be used, after thickening the solution to a paste by rubbing in whiting. The paste is applied to the previously zincked metals by means of a cork, piece of leather, or a brush. Martin and Peyraud, the originators of this method, describe the operation as follows: Articles of other metals than zinc are placed in a bath consisting of concentrated solution of sal ammoniac, in which has been placed a quantity of granulated zinc. The articles are allowed to boil a few minutes, whereby they acquire a coating of zinc. For the preparation of the gilding composition, dissolve 11.28 drachms of chloride of gold in a like quantity of water, and add a solution of 2.11 ozs. of potassium cyanide in as little water as possible (about 2.8 ozs.).

Of this solution add so much to a mixture of 3.52 ozs. of fine whiting and 2.82 drachms of pulverized tartar that a paste is formed which can be readily applied with a brush to the article to be gilded. When the article is coated, heat it to between 140° and 158° F. After removing the dry paste by washing the gilding appears and can be polished with the burnisher.

Fire or mercury gilding.—Before the introduction of electroplating, nearly all substantial gilding was effected by this process. However, the cost is much greater, the execution of the process presenting many difficulties, and besides the workman is constantly exposed to the very injurious mercurial vapors. The resulting gilding, however, is distinguished by great solidity.

The execution of fire gilding begins with the preparation of the amalgam of gold. For this purpose put a weighed quantity of fine gold in a crucible and heat to dull redness. The requisite proportion of mercury, 8 parts to 1 of gold, is now added, and the mixture is stirred with a slightly crooked iron rod, the heat being kept up until the gold is entirely dissolved by the mercury. Pour the amalgam into a small dish about 3 parts filled with water and work about with the fingers under the water to squeeze out as much of the excess of mercury as possible. To facilitate this the dish is slightly inclined to allow the superfluous mercury to flow from the mass, which soon acquires a pasty condition capable of receiving the impression of the fingers. Afterward squeeze the amalgam in a chamois leather bag, by which a further quantity of mercury is liberated. The amalgam, which remains after this final treatment, consists of about 33 parts of mercury and 57 parts of gold in 100 parts. The mercury which is pressed through the bag retains a good deal of gold, and is employed in preparing fresh batches of amalgam. It is important that the mercury employed should be pure.

To apply the amalgam, a solution of nitrate of mercury is employed, which is prepared by dissolving in a glass flask 100 parts of mercury in 110 parts of nitric acid of specific gravity 1.33, gentle heat being employed to assist the chemical action. The red fumes given off must be allowed to escape into the chimney, since they are very deleterious when inhaled. When the mercury

is all dissolved the solution is to be diluted with about 25 times its weight of distilled water and bottled for use.

The pasty amalgam is spread with the blade of a knife upon a hard, flat stone. The article, after being well cleaned and scratch-brushed, is treated as follows: Take a small scratch-brush, formed of stout brass wire, dip in the solution of nitrate of mercury, then draw over the amalgam; pass the brush carefully over the surface to be gilded, repeatedly dipping the brush in the mercurial solution and drawing it over the amalgam until the entire surface is uniformly and sufficiently coated. Then rinse the article well, and dry. The next operation is the evaporation of the mercury. For this purpose a charcoal fire, resting upon a cast-iron plate, has been generally adopted, a simple hood of sheet-iron being the only means of protection from the injurious effects of the mercurial vapors. When the amalgamated article is rinsed and dried, it is exposed to the glowing charcoal, turned about and heated by degrees to the proper point, then it is withdrawn from the fire by means of long pincers or tongs. The article is then taken in the left hand, which should be protected with a leather glove, turned over the fire in every direction, and while the mercury is volatilizing the article should be struck with a long-haired brush to equalize the amalgam coating and force it upon such parts as may appear to require it. When the mercury has become entirely volatilized the gilding has a dull, greenish-yellow color. If any bare places are apparent, they are touched up with amalgam and the article is again submitted to the fire, care being taken to expel the mercury gradually. The article is then well scratch-brushed; when it is of a pale greenish color heat it again to expel any remaining mercury, when it acquires the orange-yellow of fine gold. If required to be bright, it is burnished in the ordinary way. If the gilding is to be dead, secure the article by means of iron wire to the end of an iron rod and coat it with a hot paste consisting of saltpetre, common salt, and alum; then expose the article to a bright fire, turning it in every direction until the coat of the mixture fuses and begins to run off; then remove the article from the fire and throw it in a wooden vat containing a large quantity of water. The coat of salts covering the article is immediately dissolved, and the gilding

presents a beautiful dead appearance. To stand this process of deadening the article must be well gilded, especially, as frequently happens, if the operation does not succeed the first time.

Red streaks are frequently observed on otherwise successful gilding. These streaks are caused by the iron wire which has been wrapped round the article. They disappear by plunging the article in dilute nitric acid, or, still better, in pure hydrochloric acid.

For the sake of completeness, a method of gilding which gives to some parts of the article a lustrous and to others a dead appearance may here be mentioned. It is a combination of fire-gilding with electro-deposition, the dead places being produced by the former operation and the lustrous places by the latter. The operation is as follows : The places which are to be dead are first gilded with amalgam, heated, scratch-brushed, and raised. The entire article is then gilded with the assistance of the battery, no attention being paid to any gold depositing upon the surfaces already gilded. The entire surface is then carefully scratch-brushed, and the electro-gilded surfaces are next coated with a paste of flake-white, water, and glue, and then with a thick paste of clay, the fire-gilded surfaces remaining free. The whole is then allowed to dry, when the fire-gilded surfaces are deadened by being treated, as above described, with a hot paste of saltpetre, common salt, and alum, the coatings of flake-white and clay are then dissolved by means of water acidulated with hydrochloric acid. The only purpose of these coatings is to prevent a too intense action of the heat upon the electro-gilded portions. The latter, if necessary, are then again scratch-brushed, which must, however, be done with the greatest care, to avoid injury to the dead portions. The article is finally polished.

The method above described is generally used, but it has many disagreeable features, amongst others, that the places which are exposed to too strong a heat, or which have not been sufficiently gilded, frequently show red stains.

The following process is better and more convenient :—

The surfaces, which are to remain dead, are first gilded and deadened, and then coated with varnish. When dry the article is pickled ; the acid does not attack the varnished surfaces. The

object is then brought into the electro-gilding bath, which also does not attack the varnish. When the desired shade of gold has been obtained, the article is taken from the bath and the varnish removed by means of benzine. The article is then washed in a warm potassium cyanide solution, next in boiling water, and finally dried. The dead gilding, no matter by which process it may have been produced, is only suitable for articles not exposed to friction, a slight touch with the fingers being sufficient to deprive it of its delicate lustre.

Old dead gilding may be improved by boiling with potash and washing in dilute sulphuric or nitric acid. This suffices for the removal of stains caused by grease, smoke, or dust. If, however, the gilding is worn off, the article has to be scratch-brushed and regilt.

Du Fresne gives a method of gilding, which is also a combination of fire-gilding with electro-deposition. It is executed as follows :—

The articles are galvanized with the assistance of the current, in a mercurial solution consisting of cyanide of mercury in potassium cyanide with additions of carbonate and phosphate of soda, then gilded in an ordinary gilding bath, next again coated with mercury, then again gilded, and so on, until a deposit of sufficient thickness is obtained. The mercury is then evaporated over glowing coals, and the articles, after scratch-brushing, are burnished.

According to another process, the articles are gilded in a bath consisting of 98 per cent. potassium cyanide 1.2 ozs., cyanide of gold $92\frac{1}{2}$ grains, cyanide of mercury $92\frac{1}{2}$ grains, distilled water 1 quart, a strong current being used. The articles being sufficiently gilded, the mercury is evaporated, the articles scratch-brushed and finally polished.

Removing gold from gilded articles — "Stripping."— Gilded articles of *iron* and *steel* are best stripped by treating them as the anode in a solution of from 2 to $2\frac{3}{4}$ ozs. of 98 per cent. potassium cyanide in 1 quart of water, and suspending a copper plate greased with oil or tallow as the cathode. Gilded *silverware* is readily stripped by heating to glowing and then immersing in dilute sulphuric acid, whereby the layer of gold cracks off, the

glowing and immersing in dilute sulphuric acid being repeated until all the gold is removed. Before glowing and immersing in dilute sulphuric acid, the articles may first be provided with a coating of a paste of sal ammoniac, flowers of sulphur, borax, and nitrate of potash, which is allowed to dry. On the bottom of the vessel containing the dilute sulphuric acid the gold will be found in laminæ and scales, which are boiled with pure sulphuric acid, washed, and finally dissolved in aqua regia, and made into chloride of gold or fulminating gold.

To strip articles of *silver*, *copper*, or *German silver* which will not bear glowing, the solution of gold may be effected in a mixture of 1 lb. of fuming sulphuric acid, 2.64 ozs. of concentrated hydrochloric acid, and 1.3 ozs. of nitric acid of 40° Bé. Dip the articles in the warm acid mixture and observe the progressive action of the mixture by frequently removing the articles from it. The articles to be treated must be perfectly dry before immersing in the acid mixture, and care must be had to preserve the latter from dilution with water in order to prevent the acids from acting upon the basis-metal.

Determination of genuine gilding.—Objects apparently gilded are rubbed upon the touchstone and the streak obtained is treated with pure nitric acid of 1.30 to 1.35 specific gravity. The metal contained in the streak thereby dissolves, and as far as it is not gold disappears, while the gold remains behind. The stone should be thoroughly cleansed before each operation, and the streak should be made not with an edge or a corner of the object to be tested, but with a broader surface. If no gold remains upon the stone, but there is, nevertheless, a suspicion of the article being slightly gilded, proceed with small articles as follows: Take hold of the article with a pair of tweezers, and after washing it first with alcohol, and then with ether, and drying upon blotting paper, pour over it in a test glass, cleansed with alcohol or ether, according to the weight of the article, 0.084 to 5.64 drachms of nitric acid of 1.30 specific gravity free from chlorine. The article will be immediately dissolved, and if it has been gilded never so slightly, perceptible gold spangles will remain upon the bottom of the glass.

Recovery of gold from gold baths, etc.—To recover the gold from old cyanide gilding baths, evaporate the bath to dryness, mix the residue with litharge, and fuse the mixture. The gold is contained in the lead button thus obtained. The latter is then dissolved in nitric acid, whereby the gold remains behind in the form of spangles. These spangles are filtered off and dissolved in aqua regia.

The following method is used for the recovery of gold by the *wet process:* The bath containing gold, silver, and copper is acidulated with hydrochloric acid, which causes a disengagement of hydrocyanic acid. This gas is extremely poisonous, for which reason the operation should be carried on in the open air or where there is a good draught or ventilation to carry off the fumes. A precipitate consisting of the cyanides of gold and copper and chloride of silver is formed. This is well washed and boiled in aqua regia, which dissolves the gold and copper as chlorides, leaving the chloride of silver behind. The solution containing the gold and copper is evaporated nearly to dryness in order to remove the excess of acid, the residue is dissolved in a small quantity of water, and the gold precipitated therefrom as a brown metallic powder by the addition of sulphate of iron (copperas). The copper remains in solution.

Finely divided zinc—so-called zinc-dust—is an excellent agent for the precipitation of gold in a pulverulent form from cyanide gilding baths. By adding zinc-dust to an exhausted cyanide gilding bath, and thoroughly shaking or stirring it from time to time, all the gold is precipitated in two or three days. The quantity of zinc required for precipitation depends of course on the quantity of gold present, but, generally speaking, $\frac{1}{2}$ or at the utmost 1 lb. of zinc-dust will be required for 100 quarts of exhausted gilding bath.

The pulverulent gold obtained is washed, treated first with hydrochloric acid to remove adhering zinc-dust, and next with nitric acid to free it from silver and copper.

From the *acid mixtures* serving for dead pickling gold, or for stripping, the gold is precipitated by solution of sulphate of iron (copperas) added in excess. The gold present is precipitated as a brown powder mixed with ferric oxide. This powder is filtered

off and treated in a porcelain dish with hot hydrochloric acid, which dissolves the iron. The gold which remains behind is then filtered off, and, after washing, dissolved in aqua regia in order to work the solution into fulminating gold or neutral chloride of gold.

CHAPTER XI.

DEPOSITION OF PLATINUM AND PALLADIUM.

1. *Deposition of Platinum.*

Properties of platinum.—Pure platinum is white with a grayish tinge; it is as soft as copper, malleable, and very ductile. At a white heat it can be welded, but is fusible only with the oxyhydrogen blowpipe or by the electric current. Its specific gravity is 21.4.

Air has no oxidizing action upon platinum; it is scarcely acted upon by any single acid; prolonged boiling with concentrated sulphuric acid appears to dissolve the metal slowly. The best solvent for it is aqua regia, which forms the tetrachloride, $PtCl_4$. Chlorine, bromine, sulphur, and phosphorus combine directly with platinum, and fusing saltpetre and caustic alkali attack it.

Besides in the malleable and fused state, platinum may be obtained as a very finely divided powder, the so-called *platinum black,* which is precipitated with zinc from dilute solution of platinum chloride acidulated with hydrochloric acid.

Platinum baths.—The platinum baths formerly proposed did not yield quite satisfactory results, the content of platinum being too small in some of them, while with others dense deposits could not be obtained. A new formula by Böttger gives, however, quite a good bath: A moderately dilute solution of sodium citrate is added to platoso-ammonium chloride, until an excess of the latter no longer dissolves, even after continued boiling. The following proportions have been found very suitable: Dissolve $17\frac{1}{2}$ ozs. of citric acid in 2 quarts of water, and neutralize with caustic soda. To the boiling solution add, with constant stirring,

the platoso-ammonium chloride freshly precipitated from 2.64 ozs. of chloride of platinum, heat until solution is complete, allow to cool, and dilute with water to 5 quarts. To decrease the resistance of the bath, 0.7 or 0.8 oz. of sal ammoniac may be added; a larger addition, however, causing the separation of dark-colored platinum.

The platoso-ammonium chloride is prepared by adding to a concentrated solution of chloride of platinum concentrated solution of sal ammoniac until a yellow precipitate is no longer formed on adding a further drop of sal ammoniac. The precipitate is filtered off and brought into the boiling solution of sodium citrate. This bath works very uniformly if the content of platinum is from time to time replenished.

"The Bright Platinum Plating Company," of London, has recently patented the following composition of a platinum bath: Chloride of platinum 0.98 oz., sodium phosphate 19¾ ozs., ammonium phosphate 3.95 ozs., sodium chloride 0.98 oz., and borax 0.35 oz., are dissolved, with the aid of heat, in 6 to 8 quarts of water, and the solution is boiled for 10 hours, the water lost by evaporation being constantly replaced. The results obtained with this bath were not much better than with Böttger's.

Dr. W. H. Wahl gives the following directions for preparing platinum baths:*—

Alkaline platinate bath.—Platinic hydrate 2 ozs., caustic potassa (or soda) 8 ozs., distilled water 1 gallon.

Dissolve one-half of the caustic potassa in a quart of distilled water, add to this the platinic hydrate in small quantity at a time, facilitating solution by stirring with a glass rod. When solution is effected, stir in the other half of alkali dissolved in a quart of water; then dilute with enough distilled water to form one gallon of solution. To hasten solution, the caustic alkali may be gently heated, but this is not necessary, as the platinic hydrate dissolves very freely. This solution should be worked with a current of about two volts, and will yield metal of an almost silvery whiteness upon polished surfaces of copper and brass, and quite freely. There should be slight, if any, perceptible evolution of hydrogen

* Journal of the Franklin Institute, July, 1890.

at the cathode, but a liberal evolution of oxygen at the anode. An addition of a small proportion of acetic acid to this bath improves its operation where a heavy deposit is desired. The anode must be of platinum or carbon, and owing to the readiness with which the metal is deposited an excess of anode-surface is to be avoided. Articles of steel, nickel, tin, zinc, or German silver will be coated with black and more or less non-adherent platinum; but by giving objects of these metals a preliminary thin electro-deposit of copper in the hot cyanide bath they may be electro-platinized in the alkaline platinate bath equally as well as copper. The bath may be worked hot or cold, but it is recommended to work it at a temperature not exceeding 100° F. It may be diluted to one-half the strength indicated in the formula and still yield excellent results. The surface of the objects should be highly polished by buffing or otherwise prior to their introduction into the bath, if the resulting deposit is designed to be brilliant.

The deposition of platinum takes place promptly. In five minutes a sufficiently heavy coating will be obtained for most purposes. The deposited metal is so soft, however, that it requires to be buffed very lightly. A heavier deposit will appear gray in color, but will accept the characteristic lustre of platinum beneath the burnisher.

An oxalate solution is prepared by dissolving 1 oz. of platinic hydrate in 4 ozs. of oxalic acid and diluting the solution to the volume of one gallon with distilled water. The solution should be kept acidified by the occasional addition of some oxalic acid. The simplest plan of using this bath, which requires no attention to proportions, is simply to work with a saturated solution of the oxalate, keeping an undissolved excess always present at the bottom of the vessel. An addition of a small quantity of oxalic acid now and then will be found advantageous. The double salts of oxalic acid with platinum and the alkalies may be formed by saturating the binoxalate of the desired alkali with platinic hydrate and maintaining the bath in normal metallic strength by the presence of an undissolved residuum of platinous oxalate.

The double oxalates are not so soluble in water as the simple salt. The oxalate baths, both of single and double salts, may be

worked cold or hot (though not to exceed 150° F.) with a current of comparatively low pressure. The metal will deposit bright, reguline, and adherent on copper and brass. Other metallic objects must receive a preliminary coppering as above. The deposited metal is dense, with a steely appearance, and can be obtained of any desired thickness.

The deposit obtained in the oxalate bath is sensibly harder than that from the alkaline platinate bath and will bear buffing tolerably well.

The *phosphate bath* may be prepared by the following formula:

Phosphoric acid, syrupy (specific gravity 1.7), 8 ozs., platinic hydrate 1 to $1\frac{1}{2}$ ozs., distilled water 1 gallon.

The acid should be moderately diluted with distilled water and the solution of the hydrate effected at the boiling temperature. Water should be added cautiously from time to time to supply that lost by evaporation. When solution has taken place, the same should be diluted with sufficient water to make the volume 1 gallon. The solution may be worked cold or heated to 100° F., and with a current much stronger than that required for the platinates and oxalates. The ammonio (and sodio) platinic phosphates may be formed from the simple phosphate by carefully neutralizing the solution of the phosphate with ammonia (or soda); then adding an excess of phosphoric acid, or enough to dissolve the precipitate formed, and an additional quantity to insure a moderate amount of free phosphoric acid in the bath. The phosphate baths will be maintained of normal strength by additions of platinic hydrate, the solutions of which will need to be assisted by heating the bath, preferably at the close of each day's work. The metal yielded by the electrolysis of these phosphate solutions is brilliant and adherent. It has the same steely appearance as that exhibited by the oxalate solutions, but to a less pronounced degree. The physical properties of the deposited metal are in other respects like those described in connection with that obtained from the oxalate baths.

Management of platinum baths.—Copper and brass may be directly coated with platinum, but iron, steel, and other metals have to be previously coppered; without preliminary coppering these metals would soon decompose the platinum bath, indepen-

dent of the fact that no perfect deposit of platinum can be produced upon them without the cementing intermediary layer of copper.

Platinum baths must be used hot, and even then require a current of 5 to 6 volts. An abundant evolution of gas must appear on the objects and the anodes; the anode-surface (platinum anodes) must not be too small, and should be only at a few centimetres distance from the objects. Since the platinum anodes do not dissolve, the content of platinum in the bath becomes constantly smaller, and the bath must from time to time be strengthened. It is then heated in a porcelain dish or enamelled vessel to the boiling-point, some fresh solution of sodium citrate is added, and platoso-ammonium chloride introduced as long as solution takes place. A concentrated solution of platoso-ammonium chloride may be kept at hand and a small quantity of it at intervals be added to the bath.

Execution of platinizing.—The objects thoroughly freed from grease and pickled, and, if necessary, coppered, are suspended in the bath heated to between 176° and 194° F.; this temperature must be kept up during the entire operation. The current should be of sufficient strength and the anodes placed so close to the objects that a liberal evolution of gas appears on the anodes. For platinizing large objects it is recommended to go round them, at a distance of 0.31 to 0.39 inch, with a hand-anode of platinum sheet, which should not be too small and should be connected to the anode-rod. When the current has vigorously acted for 8 to 10 minutes, the objects are taken from the bath, dried, and polished. However, for the production of heavy deposits—for instance, upon points of lightning-rods—the deposit is vigorously brushed with a steel-wire scratch-brush or fine pumice powder. The objects are then once more freed from grease and returned for 10 to 15 minutes longer to the bath to receive a further deposit of platinum with a weaker current, which must, however, be strong enough to cause the escape of an abundance of gas bubbles. The objects are then taken out, and, after immersion in hot water, dried in sawdust. The deposit is then well burnished, first with the steel tool, and finally with the stone, whereby the gray tone disappears and the deposit shows the color and lustre of massive

platinum sheet. Points of lightning-rods platinized in this manner were without flaw after an exposure to atmospheric influences for more than six years.

Platinizing of glass.—Glass may be platinized by means of the galvanic current as follows: Dissolve 14 drachms of platinic hydrate in 17½ ozs. of a 10 per cent. solution of caustic soda or potash. Add to the solution 17½ ozs. more of the alkali solution and dilute with water to 2 quarts. The temperature of the bath should not exceed 100° F., and the strength of the current should be 2 volts.

Platinizing by contact.—Though a thick deposit cannot be produced by the contact-process, Fehling's directions may here be mentioned as suitable for giving a thin coat of platinum to fancy articles. He recommends a solution of 5.64 drachms of chloride of platinum and 7 ozs. of common salt in 1 quart of water, which is made alkaline by the addition of a small quantity of soda lye, and for use heated to the boiling point.

If larger articles are to be platinized by contact, free them from grease, and after pickling, and, if necessary, coppering, wrap them round with zinc wire or place them upon a bright zinc sheet and introduce them into the heated bath. All the remaining manipulations are the same as in other contact processes.

Recovery of platinum from platinum solutions.—From not too large baths, precipitation of the platinum with sulphuretted hydrogen is the most suitable method and preferable to evaporating and reducing the metal from the residue. The process is as follows: Acidulate the platinum solution with hydrochloric acid, and, after warming it, conduct sulphuretted hydrogen into it. The metal (together with any copper present) precipitates as sulphide of platinum. The precipitate is filtered off, dried, and glowed in the air, whereby metallic platinum remains behind. From larger baths the platinum may be precipitated by suspending bright sheets of iron in the acidulated bath. In both cases the precipitated platinum is treated with dilute nitric acid in order to dissolve any copper present. After filtering off and washing the pure platinum, dissolve it in aqua regia; the solution is then evaporated to dryness in the water bath, and the chloride of platinum thus obtained may be used in making a new bath.

2. *Deposition of Palladium.*

Properties of palladium.—Palladium, when compact, has a white color and possesses a lustre almost equal to that of silver. Its specific gravity is about 12.0; it is malleable and ductile, and may be fused at a white heat. In the oxyhydrogen flame it is volatilized, forming a green vapor. It is less permanent in the air than platinum. It is dissolved by nitric acid; it is scarcely attacked, however, by hydrochloric or sulphuric acid; hydriodic acid and free iodine coat it with the black palladium iodide.

On account of the high price of its salts, palladium has been but little used for electro-plating purposes, nor, for the same reason, is it likely to be more extensively employed in the future.

According to M. Bertrand, the most suitable bath consists of a neutral solution of the double chloride of palladium and ammonium, which is readily decomposed by 3 Bunsen elements coupled one behind the other (therefore about 5.4 volts). A sheet of palladium is used as anode.

A solution of palladium cyanide in potassium cyanide does not yield as good results as the above.

Palladium has of recent years been much used to plate watch movements. According to M. Pilet, 4 milligrammes (about $\frac{1}{17}$ grain) of palladium is sufficient to coat the works of an ordinary sized watch. M. Pilet recommends the following bath: Water 2 quarts, chloride of palladium $5\frac{1}{2}$ drachms, phosphate of ammonia $3\frac{1}{2}$ ozs., phosphate of soda, $17\frac{1}{2}$ ozs., benzoic acid $2\frac{3}{4}$ drachms. This bath is suitable for all metals except zinc.

CHAPTER XII.

DEPOSITION OF TIN, ZINC, LEAD, AND IRON.

1. *Deposition of Tin.*

Properties of Tin.—Tin is a white, highly lustrous metal; it possesses but little tenacity, but has a high degree of malleability; tin-foil may be obtained in leaves less than $\frac{1}{50}$th of a millimetre in thickness. Tin melts at about 446° F. and evaporates at a high temperature; the fused metal shows great tendency to crystallize on congealing. By treating the surface of melted tin with a dilute acid, the crystalline structure appears as designs (*moiré métallique*), resembling the ice-flowers on frosted windows.

Tin remains quite constant even in moist air, and resists the influence of an atmosphere containing sulphuretted hydrogen. Strong hydrochloric acid quickly dissolves tin on heating, evolving hydrogen and forming stannous chloride. Dilute sulphuric acid has but little action on the metal; when heated with concentrated sulphuric acid, sulphur dioxide is evolved. Dilute nitric acid dissolves tin in the cold without evolution of gas; concentrated nitric acid acts vigorously upon the metal, whereby oxide of tin, which is insoluble in the acid, is formed. Alkaline lyes dissolve the metal to sodium stannate, hydrogen being thereby evolved.

Tin baths.—The bath used by Roseleur for tinning with the battery works very well, and is composed as follows: I. Pyrophosphate of soda 3.5 ozs., tin salt (fused) 0.35 oz., water 10 quarts. To prepare the bath dissolve the pyrophosphate of soda in 10 quarts of rain-water, bring the tin-salt in a small linen bag into the solution, and move the bag to and fro until its contents are entirely dissolved.

Objects of zinc, copper, and *brass* are directly tinned in this bath with a current of slight tension. Articles of *iron* and *steel* are first coppered or preliminarily tinned in a bath prepared according

to formula VIII., the deposit of tin being then augmented in bath I. with the battery current. Cast-tin anodes as large as possible are used, which, however, will not keep the content of tin in the bath constant. It is therefore necessary, from time to time, to add tin-salt, which is best done by preparing a solution of 3.5 ozs. of pyrophosphate of soda in 1 quart of water and introducing into the solution tin salt as long as the latter dissolves clear. Of this tin essence add to the bath more or less, as may be required, and also augment the content of pyrophosphate of soda, if, notwithstanding the addition of tin-salt, the deposition of tin proceeds sluggishly.

Though the bath composed according to formula I. suffices for most purposes, an alkaline tin bath, first proposed by Elsner and later recommended by Maistrasse, Fearn, Birgham, and others, with or without addition of potassium cyanide, may be mentioned :—

II. Crystallized tin-salt 0.7 oz., water 1 quart, and potash lye of 10° Beaumé until the precipitate formed dissolves.

As seen from the formula the solution of tin-salt is compounded with potash lye of the stated concentration (or with a solution of 1 oz. of pure caustic potash in water), until the precipitate of stannous hydrate again dissolves.

Some operators recommend the addition of 0.35 oz. of potassium cyanide to the solution.

Without potassium cyanide the bath requires 3.75 to 4 volts, and with it 3.5 volts.

In testing Salzède's bronze bath (p. 211), it was found to yield quite a good deposit of tin directly upon *cast-iron*, and it was successfully used for this purpose by omitting the cuprous chloride and using 14.11 drachms of stannous chloride, so that the composition became as follows :—

IIa. 98 per cent. potassium cyanide 3.5 ozs., carbonate of potassium 35¼ ozs., stannous chloride 14.11 drachms, water 10 quarts. With 4 volts a heavy deposit was rapidly obtained.

III. A tin bath of stannous chloride, caustic soda, and potassium cyanide, given by Pfanhauser, contains 11¼ drachms of stannous chloride, equal to about 7½ drachms of metallic tin per

quart. It is still more advantageous to use double the quantity of tin, the composition of the bath being then as follows :—

Water 10 quarts, fused stannous chloride 14 ozs., caustic soda $17\frac{1}{2}$ ozs., 100 per cent. potassium cyanide $3\frac{1}{2}$ ozs.

The bath, as above composed, contains about 15 drachms of metallic tin per quart, and with $3\frac{1}{2}$ volts furnishes a deposit of tin of about $4\frac{3}{4}$ grains per hour.

Pfanhauser has recently made new experiments and found that still more favorable results are obtained with a solution of $1\frac{1}{2}$ ozs. of stanno-ammonium chloride in 1 quart of water, a deposit of $9\frac{1}{2}$ grains of tin per hour being obtained with a current of only $1\frac{1}{2}$ volts.

The solution of the salt is readily effected. Cast-tin anodes are to be used.

The temperature of the bath should be between 68° and 77° F. In case the bath becomes poor in metal, stanno-ammonium chloride is added.

The deposit of tin is rather rough, but can be readily made bright by treatment with brass scratch-brushes.

IV. A tin bath given by Taucher is composed as follows: Water 500 quarts, sodium or pyrophosphate 11 lbs., crystallized tin-salt 21 ozs., or, still better, fused tin-salt $17\frac{1}{2}$ ozs.

Bring the water into a tank completely lined with plates or anodes of tin joined together and connected with the positive pole wire. Dissolve the pyrophosphate in the water, stirring constantly. Place the tin-salt in a copper-sieve, and immerse the latter about one-half in the solution; an abundant milky turbidity is immediately formed, which, however, disappears on stirring. When all the tin-salt is dissolved, remove the sieve, and the tin-bath, which now forms a clear fluid, either colorless or of a slightly yellowish color, is ready for use, it being only necessary to secure the articles to be tinned to the rods connected with the negative pole. The anodes do not suffice to keep the bath saturated, and hence, when the deposit becomes weaker, small quantities of equal parts of tin-salt and of sodium pyrophosphate have to be added. The solution of these salts should always be effected with the assistance of a sieve to prevent small pieces of tin-salt from falling to the bottom of the bath, where they would be

enveloped by an almost insoluble crust and remain nearly unchanged.

This tin bath is suitable for all kinds of metals, the deposit obtained combining with considerable solidity a matted and white appearance closely resembling silver.

Management of tin baths.—Tin baths should not be used at a temperature below 68° F.; they require (formulæ I. and II.), according to their composition, a current of 2 to 3 volts, so that two Bunsen elements coupled one after the other suffice for all purposes. Too strong a current causes a pulverulent reduction of the tin, which does not adhere well, while with a suitable current-strength quite a dense and reguline deposit is obtained. Cast-tin plates with as large a surface as possible are used as anodes. The choice of the tin-salt exerts some influence upon the color of the tinning. By using, for instance, crystallized tin-salt, which is always acid, in preparing the bath according to formula I., a beautiful white tinning with a bluish tinge is obtained, which, however, does not adhere as well as that produced with fused tin-salt. Again, the latter yields a somewhat dull gray layer of tin, and, therefore, the effects of the bath will have to be corrected by the addition of one or the other salt.

As previously mentioned, *iron* and *steel objects* are best subjected to a light preliminary tinning by boiling in the bath VIII.; however, instead of this preliminary tinning, they may first be electro-coppered and, after scratch-brushing the copper deposit, brought into the tin bath.

When the action of the bath becomes sluggish, it has to be refreshed (for formula I.) by the addition of tin salt and pyrophosphate of soda, or (for formula II.) by the addition of potash lye and tin-salt.

From what has been said it will be clear that the *execution of tinning* is simple enough. After freeing from grease and pickling the objects are brought into the bath and tinned with a weak current. For heavy deposits of tin the objects are frequently taken from the bath, and the deposit is thoroughly brushed with a brass scratch-brush, not too hard, and moistened with dilute sulphuric acid (1 part acid of 66° Bé. to 25 water), when, after rinsing in water, the articles are returned to the bath. If, with the use of

too strong a current the color of the deposit is observed to turn a dark dull gray, scratch-brushing must be repeated. When the tinning is finished the articles are brushed with a brass scratch-brush and decoction of soap root, then dried in sawdust and polished with fine whiting.

Tinning by contact and boiling.—For tinning by zinc contact in the boiling tin bath the following solutions may be recommended:—

V. According to Gerhold: Pulverized tartar and alum, of each, 3.5 ozs., fused stannous chloride 14 drachms, rain-water 10 quarts.

VI. According to Roseleur: Potassium pyrophosphate 7 ozs., crystallized stannous chloride (tin-salt), 11 drachms, fused stannous chloride 2.8 ozs., rain-water 10 quarts.

VII. According to Roseleur, for tinning by *immersion:* Potassium pyrophosphate 5.6 ozs., fused stannous chloride 1.23 ozs., rain-water 10 quarts.

Formulæ V. and VI. yield good results. For tinning by contact, heat the bath to boiling and suspend the clean and pickled objects in contact with pieces of zinc, or, better, wrapped around with zinc wire spirals, care being had from time to time to shift them about to prevent staining. Large baths which cannot be readily heated are worked cold, the objects being covered with a large zinc plate; in the cold bath the formation of the tin deposit requires, of course, a longer time. By using the electric current the deposit can be made as heavy as desired. By immersion in the bath prepared according to formula VII. zinc can only be coated with a very thin film of tin, which, however, can be made as heavy as desired by the use of a battery.

For tinning by contact in a cold bath, Zilken has patented the following solution: Dissolve with the aid of heat in 100 quarts of water, tin-salt 7 to 10.5 ozs., pulverized alum 10.5 ozs., common salt $15\frac{3}{4}$ ozs., and pulverized tartar 7 ozs. The cold solution forms the tin bath. The objects to be tinned are to be wrapped round with strips of zinc. Duration of the process 8 to 10 hours.

Tinning solution for iron and steel articles.—VIII. Crystallized ammonium-alum 7 ozs., crystallized stannous chloride 2.8 drachms,

fused stannous chloride 2.8 drachms, rain-water 10 quarts. Dissolve the ammonium-alum in the hot water, and when dissolved add the tin-salts. The bath is to be used boiling hot and kept at its original strength by an occasional addition of tin-salt. The clean and pickled iron objects, being immersed in the bath, become in a few seconds coated with a firmly adhering film of tin of a dead white color, which may be polished by scratch-brushing or scouring with sawdust in the tumbling drum. Tinning by boiling in this bath is the most suitable preparation for iron and steel objects, which are to be provided with a heavy electro-deposit of tin. To be entirely sure of success it is recommended thoroughly to scratch-brush the objects, then to return them once more to the bath, and finally to suspend them in a bath composed according to formula I. or II.

A tinning solution for small brass and copper articles (pins, eyes, hooks, etc.) consists of a boiling solution of: Pulverized tartar 3.5 ozs., stannous chloride (tin-salt) 14.11 drachms, water 10 quarts. After heating the bath to the boiling-point immerse the objects to be tinned in a tin sieve or in contact with pieces of zinc; frequent stirring with a tin rod shortens the process.

Another solution, given by Böttger, also yields good results. Dissolve oxide of tin by boiling with potash lye, and place the copper or brass objects to be tinned in the boiling solution in contact with tin shavings.

Elsner's bath yields equally good results. It consists of a solution of equal parts of tin-salt and common salt in rain-water. The manipulation is the same as given above.

A durable coating of tin is also produced with the use of potassium stannate, which is prepared as follows: Tin is melted and then granulated by pouring it into water. The granulated tin is brought into a vessel of glass or porcelain and crude nitric acid poured over it, whereby, with strong effervescence of the fluid and the evolution of brown-red vapors, it is converted into a white powder consisting of stannic oxide. The latter is separated from the unchanged tin by washing with water, and dried. The dry powder is mixed with pure potash in the proportion of 3 parts stannic oxide and 4 parts potash. The mixture is melted in an iron crucible and the fused mass poured upon a stone-slab.

It consists of potassium stannate and is dissolved in boiling water. Potassium stannate may also be prepared by adding to a solution of tin-salt in water aqua ammonia as long as a precipitate is formed. The mass is then allowed to drain off upon a linen cloth and repeatedly washed with water. The residue, consisting of stannous hydrate, is boiled with strong potash lye and the solution of potassium stannate thus obtained diluted with water.

The tinning of needles is effected by spreading them out upon a sieve and immersing the latter in the bath; larger articles are touched with a tin-rod while in the bath. The temperature of the bath should be between 122° and 212° F. Larger articles of brass or bronze are best coppered previous to tinning, which is effected by wrapping them with iron wire and immersing them in dilute sulphuric acid for a short time; hydrochloric acid may be substituted for the sulphuric acid.

Tinning may also be effected by dissolving 1 part tin-salt in 10 parts water, adding to the solution one of 2 parts of caustic potash in 20 of water and stirring until the fluid is clear. The articles to be tinned are placed upon a tin-plate. The latter is brought into the hot bath and touched on several places with tin-rods.

To give articles of brass, copper, or iron a thin, superficial coating of tin, dip them in a solution of tin-salt in which granulated tin has been lying for some time, then dust them with tin-powder, rub them with a woollen rag, and repeat the operation until the article appears tinned.

A *characteristic method of tinning* by Stolba is as follows: Prepare a solution of 1.75 ozs. of tin-salt and 5.64 drachms of pulverized tartar in 1 quart of water; moisten with this solution a small sponge and dip the latter into pulverulent zinc. By then rubbing the thoroughly cleansed and pickled articles with the sponge they immediately become coated with a film of tin. To obtain uniform tinning, the sponge must be repeatedly dipped now into the solution and then into the zinc-powder, and the rubbing continued for a few minutes.

For coloring and platinizing tin, see special chapter.

2. *Deposition of Zinc.*

Properties of zinc.—Zinc is a bluish-white metal possessing high metallic lustre. It melts at 770° F. At the ordinary temperature zinc is brittle, but is malleable at between 212° and 300° F., and can be rolled into sheets; at 392° F. it again becomes brittle and may be readily reduced to powder. The specific gravity of zinc varies from about 6.86 to 7.2. When strongly heated in air or in oxygen it burns with a greenish-white flame, producing dense white fumes of the oxide.

In the air, zinc loses its lustre and becomes coated with a gray layer of oxide, which protects the metal beneath from further oxidation. Pure zinc dissolves slowly in the ordinary mineral acids, but the commercial article containing foreign metals is rapidly attacked with evolution of hydrogen.

Zinc being a very electro-positive metal precipitates most of the heavy metals from their solutions, especially copper, silver, lead, antimony, arsenic, tin, cadmium, etc., this being the reason why in dissolving impure zinc the admixed metals do not pass into solution so long as zinc in excess is present. Caustic alkalies also dissolve zinc with formation of an oxide and free hydrogen, especially when it is in contact with a more electro-negative metal.

Zinc baths.—Though most metals can be readily coated with a firmly adhering thin layer of zinc by the wet way and with the aid of the battery, electro-deposited zinc in comparison with that deposited by "galvanizing" is much inferior as a protective coating. It may, nevertheless, be useful to give the composition of some baths which have stood the test, as well as the most approved directions for zincking.

I. Sulphate of zinc (white vitriol) 2.8 ozs., ammonium sulphate $1\frac{3}{4}$ ozs., sal ammoniac 11 drachms, water 1 quart. Dissolve the salts in the heated water and use the bath at 68° F. The current-strength should only be slightly greater than necessary for the decomposition of the bath; the current of two Bunsen elements coupled one after the other is quite too strong, and must, therefore, be correspondingly weakened by the resistance-board.

As anodes rolled zinc sheets of not too small dimensions are to be used. This bath is suitable for heavily zincking objects (sheets and plates) of *wrought- and cast-iron, steel,* and all other metals, but not for zincking hollow articles if anodes cannot at equal distances be placed around them. The most suitable tension is 2.8 to 3 volts.

II. Caustic potash 2 ozs., chloride of zinc 5½ drachms, sal ammoniac 11 drachms, water 1 quart. Dissolve the caustic potash in one-half of the water, and the chloride of zinc and sal ammoniac in the other half, and mix the solution with stirring. The result is a clear fluid which requires a current of 2.5 to 3 volts for its decomposition. Zinc sheets are also used as anodes. In this bath the deposit upon hollow objects proceeds better than in the preceding, though frequent turning of the articles is necessary.

III. Alum 3½ ozs., hydrated oxide of zinc 5½ drachms, water 1 quart. Dissolve 14 drachms of sulphate of zinc in 1 pint of water and carefully add potash lye until a further drop of it no longer produces a precipitate. Since potash lye dissolves the hydrated oxide of zinc an excess has to be avoided. The precipitate is filtered off, washed with water, and the hydrated oxide of zinc, while still moist, is heated together with the solution of 3½ ozs. of alum in 1 quart of water, whereby it is completely dissolved. This bath requires a current of 3 to 3.5 volts.

IV. Sulphate of zinc (white vitriol) 2.8 ozs., water 1 quart, and potash lye sufficient to redissolve the precipitated hydrated oxide of tin. This bath also works quite well, and requires from 2.75 to 3 volts and 1.5 ampères per 15½ square inches.

Solution of cyanide of zinc in potassium cyanide may also be used for zincking, such a bath having been warmly recommended by some authors. However, the production of deposits of some thickness requires a long time, and the deposit itself shows a tendency to peeling off.

Execution of zincking.—Next to thorough cleansing and pickling the objects, especially iron castings, and regulating the current, electro-zincking depends on the frequent turning and changing of the objects in the bath, since the deposit is chiefly formed upon the portions nearest to the anodes, and not at all, or

with difficulty, upon the portions away from the anodes. If, notwithstanding frequent changing, some portions do not acquire a deposit, recourse must be had, as in nickelling, to the hand anode. Next to frequently changing the articles in the bath, it is recommended to scratch-brush them several times, especially if heavy deposits are to be produced. It is also advisable to somewhat heat the baths, if possible.

It is of advantage to superficially zinc iron objects by a combined process of contact and boiling, and then to augment the layer of zinc in the bath.

After thorough scratch-brushing with a steel brush, not too hard, and a decoction of soap-root, the zincked objects are rinsed in lime-water, then plunged into hot water, and dried in sawdust; polishing is effected upon soft cloth bobs with Vienna lime and oil.

For *zincking iron by contact* quite a concentrated solution of chloride of zinc and sal ammoniac in water, only, is suitable, in which the objects are placed in contact with large surfaces of zinc.

To coat brass and copper with a bright layer of zinc proceed as follows: Boil commercial zinc-gray, *i. e.*, very finely divided metallic zinc, several hours with concentrated solution of caustic soda. Then immerse the articles to be zincked in the boiling fluid, when, by continued boiling, the articles will in a short time become coated with a very bright layer of zinc. When a copper article thus coated with zinc is carefully heated in an oil bath to between 248° and 284° F., the zinc alloys with the copper, forming a sort of bronze similar to tombac.

Weil zincks copper and coppered objects by immersing them in a boiling concentrated solution of caustic potash in contact with zinc. The coating thus obtained is said to be adherent and brilliant.

For *coloring* and *platinizing zinc*, see special chapter.

Zinc alloys.—The production of the principal zinc alloy, brass, by the galvanic method, having already been mentioned, and also that of a zinc-nickel-copper alloy (German silver), it remains to give an alloy of zinc with tin which can be produced by the use of the battery.

A suitable bath for depositing this alloy consists of: Chloride of zinc 6¾ drachms, crystallized stannous chloride 9 drachms, pulverized tartar 9 drachms, pyrophosphate of soda 2¾ drachms, water 1 quart. Dissolve the salt at a boiling heat, and filter the cold solution, when it is ready for use. For anodes, cast plates of equal parts of tin and zinc are used.

3. *Deposition of Lead.*

The properties of lead only interest us in so far as it being less attacked by most mineral acids than other metals, objects have been coated with it in order to protect them against the action of such agents. For decorative purposes electro-deposits of lead are not used, and those as a protection against chemical influences cannot be produced of sufficient thickness for that purpose.

Lead baths.—I. Dissolve, by continued boiling, caustic potash 1.75 ozs. and finely pulverized litharge 0.17 oz. in 1 quart of water.

II. According to Watt, the following solution is used: Acetate of lead 0.17 oz., acetic acid 0.17 oz., water 1 quart.

The bath prepared according to formula I. deserves the preference.

Lead baths require anodes of sheet-lead or cast-lead plates, a very weak current, and in order to produce a dense deposit of some thickness the objects have to be frequently scratch-brushed. Iron is best previously coppered. Superoxide of lead being separated upon the anodes, they have to be frequently cleansed with a scratch-brush. The formation of superoxide of lead is utilized for the production of the so-called Nobili's rings (electrochromy), which will be mentioned below.

To coat *gun-barrels and other articles of steel or iron* with superoxide of lead as a protection against rust, suspend the bright articles as anodes in a solution of nitrate of lead mixed with ammonium nitrate.

Leading by contact is effected by suspending the objects, thoroughly freed from grease, in the boiling solution prepared according to formula I., in contact with a piece of tin.

Nobili's rings (*iridescent colors, electrochromy*).—The separation of superoxide of lead upon the anodes or upon objects suspended as anodes, produces superb effects of colors. For the production of such colors, a bath is prepared by boiling for half an hour 3½ ozs. of caustic potash, 14 drachms of litharge, and 1 quart of water. The operation is as follows: Suspend the articles, carefully freed from grease and pickled, to the anode-rods, and with a weak current introduce in the lead solution a thin platinum wire connected with the object-rod by flexible copper wire without, however, touching the article. The latter will successively become colored with various shades—yellow, green, red, violet, and blue. By the continued action of the current, these colors pass into a discolored brown, which also appears in the beginning if the current is too strong, or the platinum wire be immersed too deep. Such unsuccessful coloration has to be removed by rapidly dipping in aqua fortis, and, after rinsing in water, suspending the article in the bath. For coloring not too large surfaces, a medium-sized Bunsen element is, as a rule, sufficient, if the platinum wire be immersed about ¾ inch.

Colors of all possible beautiful contrasts may be obtained by perpendicularly placing between the objects to be colored and the platinum wire a piece of stout parchment paper, or providing the latter with many holes or radial segments.

4. *Deposition of Iron* (*Steeling*).

The principal practical use of the electro-deposition of iron is to cover printing plates of softer metals with a coating of "steel," to increase their wearing qualities. The steeling of printing plates, however, has no advantage over nickelling or cobalting, which has lately been introduced with the best success.

Steel baths.—I. According to Varrentrapp: Pure green vitriol 4¾ ozs., sal ammoniac 3½ ozs., water 1 quart. Boil the water for ½ hour to remove all air, and, after cooling, add the green vitriol and sal ammoniac. By the action of the air, and the oxygen appearing on the anodes, this bath is readily decomposed, insoluble basic sulphate of iron being separated as a delicate powder, which has to be frequently removed from the fluid by

filtering. To decrease decomposition, the double sulphate of iron and ammonium, which can be more readily obtained pure and free from oxide, may be used.

II. Sal ammoniac $3\frac{1}{2}$ ozs., water 1 quart. This neutral solution of sal ammoniac may be made into an iron bath by hanging in it iron sheets as anodes, suspending an iron or copper plate as cathode, and allowing the current to circulate until a regular separation of iron is attained, which is generally the case in 5 to 6 hours. Although a separation of hydrated oxide of iron also takes place in this bath, it is in a less degree than in that prepared according to formula I. For the production of not too heavy a deposit of iron, some operators claim to have obtained the best results with this bath.

For the production of electrotypes in iron the following baths (III. and IV.) are most suitable :—

III. Ammonio-ferrous sulphate $1\frac{3}{4}$ ozs., water 1 quart. The solution must be kept absolutely neutral, which according to Klein's suggestion is, on the one hand, to be attained by the use of large anode-surfaces, and, on the other, by suspending in the bath a copper plate and connecting it with the anodes. It would seem more advantageous to maintain the neutrality of the bath by suspending in it small bags filled with carbonate of magnesia.

A steel bath highly recommended by Klein consists of a solution of equal parts of green vitriol and sulphate of magnesia, which is kept neutral by bags filled with carbonate of magnesia suspended in the fluid. The most suitable concentration of the solution corresponds to a specific gravity of 1.55 ; and according to the most recent experiments, the current-density should at the utmost amount to 0.02 ampère per $15\frac{1}{2}$ square inches, with a distance of $1\frac{1}{2}$ inches of the anodes from the plate, this distance to be gradually increased.

For steeling his copper printing plates, which are frequently of quite large dimensions, C. Obernetter of Munich employs the following method : The plate to be steeled is first freed from all color, which is best effected by means of chloroform or oil of turpentine. It is then thoroughly washed and brushed by means of a bristle-brush with potash lye or a solution of 1 part potassium cyanide in 20 parts water, and again washed. In this state the

plate is suspended to the cathode of the steeling bath. A clean steel plate serves as anode. Both the anode and cathode are in a horizontal position. Bubbles forming on the cathode are readily removed by means of a feather. In about five minutes the plate is thoroughly steeled.

The iron bath consists, according to Obernetter, of ferrous sulphate 30 parts by weight, iron-alum 30, sal ammoniac 60, dissolved in warm distilled water 1000.

The solution is allowed to stand for two days, and is then filtered twice. It should also be filtered every time before use.

After steeling, the plate is cleansed in the above described manner, and oiled to prevent rusting.

When during the operation of printing the deep places of the plate commence to become red, *i. e.*, when the copper shines through, the steeled plate may be re-steeled, but, according to Obernetter, this should not be done more than once. It is best in every case to first remove the old steeling with dilute sulphuric or nitric acid, and then to re-steel the plate.

According to Obernetter's statements, 21,000 copies were printed from a plate thus steeled without the plate suffering any injury, the last impression being in every respect equal to the first.

For decorative purposes, a deep black deposit of iron may, according to "La Metallurgie," be produced as follows: Dissolve as large a quantity of steel filings as possible in 50 quarts of commercial hydrochloric acid. The saturation of the solution is recognized by a sediment, which no longer dissolves, being formed on the bottom of the vessel. Then add 2 lbs. of white arsenic, and vigorously stir the mixture. The arsenic dissolves very slowly, but the bath cannot be considered finished until all of it is dissolved, and the color obtained by means of the bath is the deeper the more complete the solution of the arsenic. The articles to be treated are connected to the negative pole of the battery, iron and carbon plates serving as anodes. For a bath of 50 quarts, two Bunsen elements about 7¾ inches high are required, and the bath being very acid, the articles must be connected with the battery prior to immersion. Upon copper and brass the deposit is directly produced, but iron articles being attacked by the bath, are first provided with a coat of nickel. The deposit of iron upon

this nickel coating is very beautiful, and has been designated as "black nickelling." The coating must, of course, be protected from oxidation by a colorless lacquer.

Management of iron baths.—As previously mentioned, the insoluble precipitate from time to time formed in the bath has to be removed by filtration. This precipitate is, however, very delicate, and when stirred up might settle upon the objects and prevent the adherence of the deposit. It is, therefore, advisable to use for steel baths, vats of much greater depth than correspond to the height of the objects, whereby the stirring up of the sediment in suspending the objects in the bath is best avoided. The baths must be kept thoroughly neutral, which may be effected in various ways. One method has already been mentioned in connection with formula III.; another method, which has been used with decided success, consists in precipitating, excluding the air as much as possible, a solution of pure green vitriol with ammonium carbonate, quickly filtering off the ferrous carbonate, washing the latter once or twice in cold water previously boiled, stirring it while moist into the bath, and allowing it to settle for one hour.

Execution of steeling.—Only the manipulations for the production of thin deposits will here be discussed. The production of heavy galvanoplastic deposits of iron will be explained later on under "Galvanoplasty."

The clean and pickled objects are coated in the baths according to formulæ I. and II. with a current of 1 to 1.25 volts, and the anodes at a distance of $3\frac{3}{4}$ to $4\frac{3}{4}$ inches, after which the current is reduced to 0.75 or 1 volt. To produce iron deposits of any kind of thickness, the escape of the hydrogen bubbles which settle on the objects must be promoted by frequent blows with the finger upon the object-rod. As anodes, iron sheets of a large surface freed from scale by pickling are to be used. When steeling is finished, the articles are thoroughly rinsed, then plunged into very hot water, and, after drying in sawdust, placed for several hours in a drying chamber heated to about 212° F., to expel all moisture from the pores.

Steeling by contact is readily effected by touching the objects with zinc, best in a bath prepared according to formula I.

CHAPTER XIII.

DEPOSITION OF ANTIMONY, ARSENIC, ALUMINIUM.

1. *Deposition of Antimony.*

Properties of antimony.—Electro-deposited antimony possesses a gray lustre, while native, fused antimony shows a silver-white color. Antimony is hard, very brittle, and may easily be reduced to powder in a mortar. It melts at 842° F., and at a strong red heat takes fire and burns with a white flame, forming the trioxide. Its density is 6.8. It is permanent in the air at ordinary temperatures. Cold, dilute, and concentrated sulphuric acid have no effect upon antimony, but the hot concentrated acid forms sulphide of antimony. By nitric acid the metal is more or less energetically oxidized, according to the strength and temperature of the acid.

Antimony baths.—Electro-depositions of antimony are but seldom made use of in the industries, though they are very suitable for the production of contrasts in decorating. Gore discovered the explosive power of depositions of antimony chloride, or of antimony containing hydrochloric acid. According to Gore, a bath consisting of tartar emetic 3 ozs., hydrochloric acid 4¼ ozs., tartaric acid 3 ozs., and water 1 quart, yields a gray crystalline deposit of antimony. This bath requires a current of about 3 volts. The deposit possesses the property of exploding when scratched with a hard object. The explosion of the deposit is caused by a content of chloride of antimony. Böttger found 3 to 5 per cent. of chloride of antimony in the deposit, and Gore 6 per cent. A similar explosive deposit is obtained by electrolyzing a simple solution of chloride of antimony in hydrochloric acid (liquid butter of antimony, *liquor stibii chlorati*) with the current.

A lustrous non-explosive deposit of antimony is obtained by boiling 4.4 ozs of carbonate of potash, 2.11 ozs. of pulverized

antimony sulphide, and 1 quart of water, for 1 hour, replacing the water lost by evaporation, and filtering. Use the bath boiling hot, employing cast antimony plates or platinum sheets as anodes.

Another antimony bath may be prepared by dissolving freshly precipitated sulphide of antimony with an excess of sulphide of ammonia. It yields a very lustrous and adherent deposit of antimony, which, in 6 to 8 minutes, is of sufficient thickness to bear polishing with Vienna lime upon rapidly revolving cloth wheels. An unpleasant feature of this bath is that during the plating process much sulphur is separated, which renders the bath turbid, so that it has to be frequently filtered. With the use of platinum anodes, this separation of sulphur is, of course, still greater than with antimony anodes.

2. *Deposition of Arsenic.*

Properties of arsenic.—Arsenic has a gray-white color, a strong metallic lustre, is very brittle, and evaporates at a red heat. In dry air arsenic retains its lustre, but soon turns dark in moist air. It is scarcely attacked by dilute hydrochloric and sulphuric acids, while concentrated sulphuric acid as well as nitric acid oxidizes it to arsenious acid. If caustic alkalies are fused together with arsenic, a portion of the latter is converted into alkaline arsenate.

Arsenic baths.—Deposits of arsenic are more frequently used than antimony deposits for decorative purposes; for instance, to color gray the dead background of brassed lamp-legs, vases, etc., while the prominent portions are bright brass. A solution suitable for depositing arsenic upon all kinds of metals is as follows:—

I. Pulverized arsenious acid $1\frac{3}{4}$ ozs., crystallized pyrophosphate of soda 0.7 oz., 98 per cent. potassium cyanide $1\frac{3}{4}$ ozs., water 1 quart.

Dissolve the pyrophosphate of soda and potassium cyanide in the cold water, and after adding, with stirring, the arsenious acid, heat until the latter is dissolved. In heating, fumes containing prussic acid escape, the inhalation of which must be carefully avoided. The bath is used warm, and requires a vigorous cur-

rent of at least 4 volts, so that, at the least, 3 Bunsen elements have to be coupled for tension. After suspending the objects they are first colored black-blue, the color passing with an increased thickness of the deposit into pale blue, and finally into the true arsenic gray. Platinum sheets or carbon plates are to be used as anodes.

Instead of a bath prepared according to formula I., a solution of the following composition may be used :—

II. Sodium arsenate $1\frac{3}{4}$ ozs., 98 per cent. potassium cyanide 0.8 oz., water 1 quart. Boil the solution for half an hour, then filter and use it at a temperature of at least 167° to 176° F., with a strong current; it yields a good deposit.

Large baths, to be used cold, must be more concentrated, and require a stronger current than hot baths.

When the baths begin to work irregularly and sluggishly, they have to be replaced by fresh solutions.

In the execution of deposits of arsenic and antimony the same rules are to be observed as for the other electro-plating processes.

Deposits of antimony and arsenic by contact and immersion are much used for coloring brass and copper, as well as iron (browning of gun-barrels) and silver. Most frequently a warm solution of antimony trichloride (the butter of antimony of commerce) in hydrochloric acid is used for this purpose, in which the clean and pickled brass articles acquire a coating of a steel-gray color with a bluish tinge. By using instead a hot mixture of chloride of arsenic with a small quantity of water, a steel-gray color without a bluish tinge is obtained.

By immersing brass in a solution of 20 parts by weight of arsenious acid, 40 of hydrochloric acid, 800 of water, and 10 of sulphuric acid heated to between 122° and 140° F., it becomes black by the separation of pulverulent arsenic; after rinsing in water and drying the coat adheres quite well. By contact with zinc the deposit is obtained in a shorter time and adheres better.

3. *Deposition of Aluminium.*

Properties of aluminium.—Aluminium is a white, silvery metal with an almost imperceptible bluish tinge. It is extremely light,

the specific gravity being only 2.58, is very malleable and ductile, takes a high polish, and is not liable to tarnish in the air. It melts at about 1300° F. Its principal common impurities are iron and silicon.

Aluminium baths.—Aluminium does not seem to possess any qualities that would make it advantageous as an electro-deposit upon other metals. Many solutions have been proposed which it was claimed should give good deposits of the metal, but have been found by various experimenters to be worthless. We therefore confine ourselves to giving only a few solutions which are claimed to give good results.

I. Bertrand states that he has deposited aluminum upon a plate of copper in a solution of the double chloride of aluminium and ammonium by using a strong current from three Bunsen elements, the bath being worked at 140° F.

II. *Goze's process.*—Mr. Goze obtained a deposit of aluminium by the single-cell method from a dilute solution of the chloride. The liquid was placed in a jar in which was immersed a porous cell containing dilute sulphuric acid; an amalgamated zinc plate was immersed in the acid solution and a plate of copper in the chloride solution, the two metals being connected by a copper conducting wire. At the end of some hours the copper plate became coated with a lead-colored deposit of aluminium, which, when burnished, presented the same degree of whiteness as platinum and did not appear to tarnish readily when immersed in cold water or exposed to the atmosphere, but was acted upon by dilute sulphuric and nitric acids.

III. The following formula is given by Mr Herman Reinbold, who states that it yields excellent results: Dissolve 50 parts by weight of alum in 300 of water and to this add 10 parts of aluminium chloride. The solution is to be heated to 200° F., and, when cold, 39 parts of potassium cyanide are to be added. A feeble current should be used.

IV. A new method for the electro-deposition of aluminium is as follows:* To a 20 per cent. solution of ammonium-alum in warm water add a solution of about the same quantity of pearl-

* Neueste Erfindungen und Erfahrungen, vol. xix. p. 353.

ash and of a small quantity of ammonium carbonate. The mixture effervesces and yields a precipitate, which is filtered off and thoroughly washed with water. Over the precipitate thus obtained pour a warm solution of 16 per cent. ammonium-alum and 8 per cent. pure potassium cyanide, and boil the whole in a closed iron vessel for 30 minutes. The proper proportions for the solutions are as follows: *First alum solution:* Ammonium-alum 4 lbs., warm water 10 quarts. *Pearl-ash solution:* Pearl-ash 4 lbs., warm water 10 quarts, ammonium carbonate $4\frac{1}{2}$ to $5\frac{1}{2}$ drachms. *Second alum solution:* Ammonium-alum 8 lbs., warm water 25 quarts, potassium cyanide 4 lbs. Then add 20 quarts of water and about 4 lbs. more of potassium cyanide, and let the whole boil for about $\frac{1}{4}$ hour. The filtered solution is then ready for use as the electrolytic bath. As anodes perforated aluminium plates are used, which can be raised and lowered. The cathodes receive the deposit. The bath is maintained at a temperature of between 80° and 149° F. By adding pieces of other metals, such as gold, silver, nickel, copper, etc., to the aluminium anodes the color of the deposit may be somewhat changed. If the deposit shows a gray coloration it is made lustrous by dipping in a solution of caustic soda, which also prevents oxidation.

The electro-deposition of tungsten, cadmium, and bismuth having, up to the present time, attained no practical importance, its discussion may be omitted.

CHAPTER XIV.

GALVANOPLASTY (REPRODUCTION).

By galvanoplasty proper is understood the production, with the assistance of the electric current, of copies of articles of various kinds, true to nature, and of sufficient thickness to form a resisting body, which may be separated from the object serving as a mould.

Copper is the most suitable metal for galvanoplastic processes, that which is precipitated by electrolysis showing the following

valuable properties: It may be precipitated chemically pure, and in this state is less capable of change than ordinary commercial copper or the ordinarily used copper alloys, its strength of extension being 20 per cent. greater than that of melted copper; its hardness is also greater than that of melted copper, while its specific gravity (8.85) lies between that of cast and rolled copper.

The physical properties of copper deposited by electrolysis are dependent on the condition of the bath as well as on the intensity and tension of the working current. The bath used for precipitating the copper is in all cases a solution of blue vitriol. Smee had originally proved by experiments that copper is obtained as a more tenacious and fine-grained deposit when the current-strength is as great as possible, without, however, evolution of hydrogen taking place; while copper in pulverulent, sandy form is obtained with a current-strength that liberates hydrogen, and in coarsely crystalline form when the current strength is very slight.

At a more recent period, von Hübl instituted a series of systematic experiments for the determination of the conditions under which deposits with different physical properties are obtained. Hübl worked with 5 per cent. neutral, and 5 per cent. acid, solutions of copper, as well as with 20 per cent. neutral, and 20 per cent. acid solutions. The neutral solutions were prepared by boiling blue vitriol solution with carbonate of copper in excess, and the acid solutions by adding 2 per cent. of sulphuric acid of 66° Bé. The result was that in the neutral 5 per cent. solutions less brittle deposits were obtained with a small current-density than in a more concentrated solution, though the appearance of the deposits was the same. The experiments with acidulated baths confirmed the fact that free sulphuric acid promotes the formation of very fine-grained deposits even with very slight current-densities, and it appears that the brittleness of copper deposited from acid baths is influenced less by the concentration than by the current-density used.

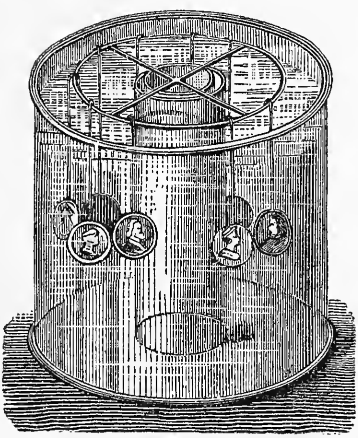
The processes used in galvanoplasty may be arranged in two classes, viz., the *deposition* of copper *with or without the use of external sources of current*, the first comprising galvanoplastic

deposits produced by means of the *single-cell apparatus,* and the other those by the battery or dynamo-machine.

1. *Galvanoplastic Deposition in the Cell Apparatus.*

The cell apparatus consists of a vessel containing blue vitriol solution kept saturated by a few crystals of blue vitriol placed in a muslin bag or a small perforated box of wood, stoneware, etc. In this vessel are placed round or square porous clay cells (diaphragms) which contain dilute sulphuric acid and a zinc plate, the zinc plates being connected with each other and with the objects to be moulded—which may be either metallic or made conductive by graphite—by copper wire or copper rods. The objects to be moulded play the same role as the copper electrode in a Daniell element, and the cell apparatus is nothing else but a species of Daniell element in which the internal, instead of an external, current is utilized. As soon as the circuit is closed by the contact of the objects to be moulded with the zinc of the porous cell, the

Fig. 118.



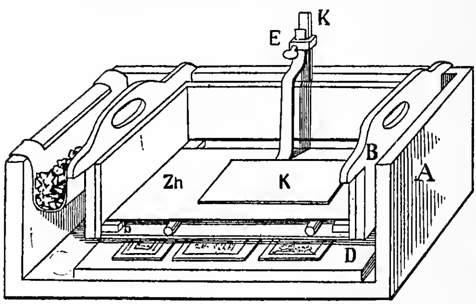
electrolytic process begins; the zinc is oxidized by the oxygen and with the sulphuric acid forms zinc sulphate (white vitriol), while the copper is reduced from the blue vitriol solution and deposited in a homogeneous layer upon the articles to be moulded.

A simple apparatus, frequently used by amateurs for moulding medals, reliefs, etc., is shown in Fig. 118.

In a cylindrical vessel of glass or stoneware filled with saturated blue vitriol solution is placed a porous clay cell, and in the latter a zinc cylinder projecting about 0.039 to 0.079 inch above the porous clay cell. To the zinc is soldered a copper ring, as plainly shown in the illustration. The clay cell is filled with dilute sulphuric acid (1 acid to 30 water), to which some amalgamating salt may be suitably added. The articles to be moulded are suspended to the copper ring, care being had to have the surfaces which are to be covered near and opposite to the cell. To supplement the content of copper, small linen or sail-cloth bags filled with blue vitriol are attached to the upper edge of the vessel.

Fig. 119 shows another form of cell-apparatus which is much used in printing establishments for the production of clichés.

Fig. 119.



A is a large box lined with gutta-percha. In this box is suspended a smaller box, *B*, the bottom of which is formed of a disk of leather or parchment. To the side of this box are nailed strips, *b*. To these strips is secured a piece of stout linen, which serves partially as a support of the zinc plate *Z n* and partially to prevent impurities of the zinc from falling upon the leather disk. The zinc plate is connected with the strap *K*, which is made of sheet copper. In the box *A* lies the board *D*, which is sufficiently weighted with strips of lead to prevent it from floating in the fluid. To prevent the separation of copper, these lead strips are coated

with a varnish made from sealing-wax or with gutta-percha. To the upper side of the board is nailed the copper strap *K′*, which is insulated as far as it touches the fluid and the board by a coating of gutta-percha. The binding screw *E* connects the two copper straps. A perforated copper sheet bent in the form of a gutter dips above in the copper solution. During the operation this copper sheet is kept filled with crystals of blue vitriol, and serves to maintain a uniform saturation of the fluid.

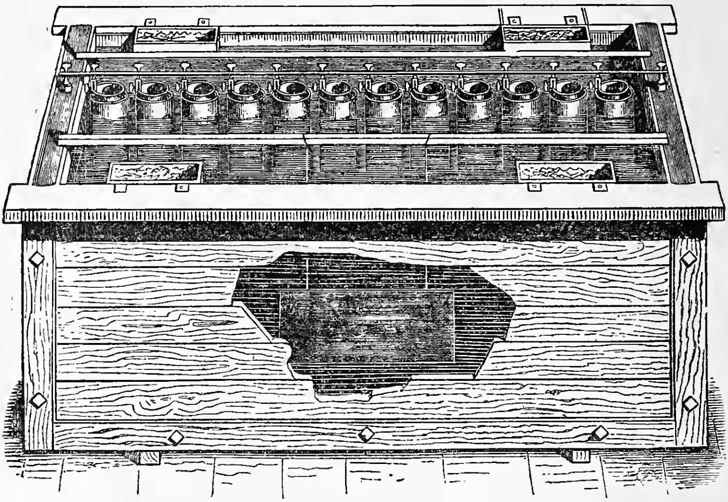
To produce deposits with this apparatus, the first matrice is laid upon the portion of copper strap upon the board *D*. The copper strap is then connected with the conducting surface by driving a brass pin through the matrice and the strap into the board. Underneath the other end of the matrice is placed a small piece of copper sheet insulated by gutta-percha, so that it projects ½ to ¾ inch beneath the matrice. It is also brought in contact with the conducting surface by means of a brass pin. Upon this sheet is placed the second matrice, which is also secured with a brass-pin, and so on, until all the moulds upon which copper is to be precipitated are upon the board. The surfaces of the moulds, as well as the heads of the pins, are then carefully rubbed with graphite, and the board is brought into the box filled with blue vitriol solution. The box *B* with the zinc plate is then suspended in the box *A*, and after filling it with dilute sulphuric acid, the two copper straps are connected by the binding screw *E*. The electric current then passes through the latter and the pin to the surface of the first matrice, and after depositing copper upon it passes through the second pin and the small copper plate to the second matrice, and so on, effecting a uniform deposit of copper upon all conducting surfaces connected with each other.

Large apparatus.—To cover large surfaces, use large, square vats of stoneware, or of wood, lined with lead, gutta-percha, or another substance unacted upon by the bath. For baths up to three feet long stoneware vats are to be preferred.

Fig. 120 shows the *French form of cell apparatus.* In the middle of the vat, and in the direction of its length, is disposed a row of cylindrical cells, close to each other, each provided with its zinc cylinder. A thin metallic ribbon is connected with all the binding screws of the cylinder, and is in contact at its extremi-

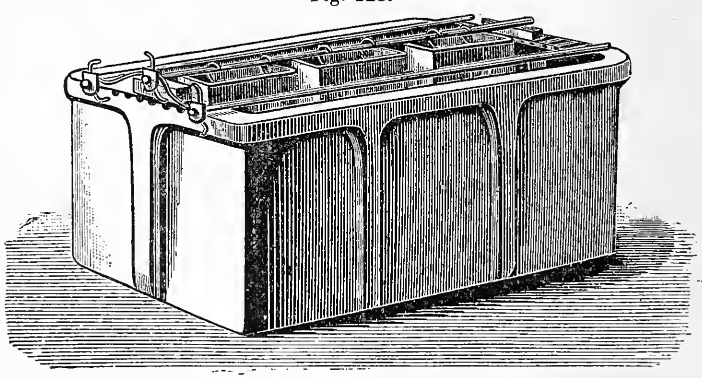
ties with two metallic bands on the ledges of the depositing vat. The metallic rods supporting the moulds are in contact with the

Fig. 120.



metallic bands of the ledges, and, therefore, in connection with the zincs.

Fig. 121.



The German form of cell apparatus is shown in Fig. 121. It is provided with long, narrow, rectangular cells of a correspondingly greater height than the column of fluid.

Across the vat are placed three conducting rods connected with each other by binding screws and copper wire. To the centre rod, which lies over the cells, are suspended the zinc plates by means of a hook, while the two outer rods serve for the reception of the moulds.

The size of the zinc surfaces in the simple apparatus should be about equal to that of the surfaces to be moulded, if dilute sulphuric acid (1.30) is to be used. For particulars see "Execution of the Galvanoplastic Deposition of Cooper."

The copper bath for the cell apparatus consists best of a moderately saturated solution of pure blue vitriol, free from iron, in water free from lime, and should show about 18° to 20° Bé., a bath of 100 quarts requiring about 20 to 24 lbs. of blue vitriol. The following table gives the approximate content of pure crystallized blue vitriol at different degrees Bé., and 59° F.

Degrees, Bé.	Weight by volume.	The solution contains crystallized blue vitriol.
5°	1.035	5 per cent.
10°	1.072	11 "
12°	1.088	13 "
15°	1.113	17 "
16°	1.121	18 "
17°	1.130	19 "
18°	1.138	20 "
19°	1.147	21 "
20°	1.157	23 "
21°	1.166	24 "
22°	1.176	25 "

While to a copper bath working with the use of an external source of current more or less sulphuric acid is added, according to requirement, baths in the single cell apparatus do not require such addition, because a considerable quantity of the acid in the clay cell gradually penetrates by osmose into the bath; and not only of the acid alone, but also of the white vitriol solution formed, whereby the working duration of the bath is considerably reduced. Furthermore, the sulphuric acid liberated by the separation of copper from the blue vitriol finds no saturation; so that such a bath finally contains an excess of acid which for the production of good deposits must from time to time be removed, if

it is not preferred to throw the bath away and make a fresh one. The simplest method of removing the excess of acid is to add to the bath pure carbonate of copper as long as strong effervescence takes place, blue vitriol being thereby formed, and hence the bath at the same time strengthened. Some operators remove the excess of acid by adding to the bath whiting free from iron, until no more effervescence takes place, and then filtering off from the calcium sulphate (gypsum) formed. The first-mentioned process is, however, preferable in every respect.

2. *Galvanoplastic Deposition by the Battery and Dynamo-Machine.*

Since it has been shown in the preceding section that a cell apparatus is to be considered as a Daniell element closed in itself, it will not be difficult to comprehend that in economical respects no advantage is offered by the production of galvanoplastic depositions by a separate battery, because in both cases the chemical work is the same and the zinc dissolved by the use of the Daniell or Bunsen element effects no greater quantity of copper deposit in the bath than the same quantity of zinc dissolved in the cells of the single apparatus. In other respects the use of a battery, however, offers great advantages. The employment of external sources of current requires the same arrangement as shown in Figs. 47 and 50, pp. 81 and 85; copper anodes being placed in the bath, which are connected with the anode pole of the battery.

By this arrangement, while the copper is being deposited upon the mould, the copper anodes become dissolved by the sulphuric acid set free, forming sulphate of copper, which continued action keeps the copper content of the bath quite constant. Furthermore, no foreign metallic admixtures reach the bath, as is the case in the single cell apparatus by the white vitriol solution penetrating from the clay cell into the bath and causing the formation of rough and brittle deposits of copper. The principal advantage, however, is that by placing a resistance board in the circuit the current-strength can be controlled so that the deposits can be quickly covered with a strong current and then augmented with a weaker current, and that by intelligently regulating the current-strength,

deep depressions can also be covered, which is difficult in the single cell apparatus.

A. *Depositions with the Battery.*

The Daniell element described on p. 32, which yields a tension of about 1 volt, is much liked for this purpose. Since the copper bath for galvanoplastic purposes requires for its decomposition an electromotive force of only 0.5 to 1 volt, it will be best for slightly depressed moulds to couple the elements for quantity (Fig. 3, p. 18), alongside of each other; and only in cases where the particular kind of moulds requires a current of stronger tension, to couple two elements for tension one after the other, an excess of current being rendered innoxious by means of the resistance board or by suspending larger surfaces.

Bunsen elements may, however, be used to great advantage, since the zincs of the Daniell elements become tarnished with copper and have to be frequently cleansed if the process is not to be retarded or entirely interrupted. The Bunsen elements need only be coupled for quantity, their electromotive power being considerably greater. To be sure, the running expenses are much greater than with Daniell elements, at least when nitric acid is used for filling. All that has been said under "Electro-plating arrangements in particular," page 76, in regard to conducting the current, the resistance boards, conducting rod, anodes, etc., is also valid for plants for the galvanoplastic deposition of copper with the battery.

B. *Depositions with Dynamo-Machines.*

It is best to use dynamos capable of yielding a large quantity of current with a tension of 2, or, at the utmost, $2\frac{1}{2}$ volts. In order to avoid repetition, the reader is referred to what has been said under "Arrangements with dynamo-electric machines," page 93, the directions given there applying also to the galvanoplastic process. Since only in very rare cases the object-surface will be the same in all baths, it will be advisable to supply each of the baths, if several of them are worked with one dynamo-machine, with a resistance-board and a voltmeter.

Copper baths for galvanoplastic depositions with a separate source of current.—The directions for the composition of the bath vary very much, some authors recommending a copper solution of 18° Bé. which is brought up to 22° Bé. by the addition of pure concentrated sulphuric acid. Others again increase the specific gravity of the bath up to 25° Bé. by the addition of sulphuric acid, while some prescribe an addition of 5 to 7 per cent. of sulphuric acid. It is difficult to give a general formula suitable for all cases, because the addition of sulphuric acid will vary according to the current-strength at disposal, the nature of the moulds, and the distance of the anodes from the objects. The object of adding sulphuric acid is, on the one hand, to render the bath more conductive and, when used in proper proportions, to make the deposit more elastic and smoother, and prevent the brittleness and coarse-grained structure which, under certain conditions, appear. When depositing with a battery somewhat more sulphuric acid may be added to the bath than when employing the current of a dynamo-electric machine. The following compositions have, in most cases, been found suitable for the reproduction of shallow as well as of deep moulds.

I. *For depositing with the dynamo.*—Blue vitriol solution of 18° Bé. 100 quarts, pure sulphuric acid of 66° Bé. 1 to 1½ quarts.

II. *For depositing with the battery.*—Blue vitriol solution of 18° Bé. 100 quarts, pure sulphuric acid of 66° Bé. 1½ to 2 quarts.

For some special uses, the composition of the bath has to be somewhat modified, which will be referred to later on. In regard to the *elasticity*, *strength*, and *hardness* of galvanoplastic depositions of copper, v. Hübel found that copper of great toughness, but of less hardness and strength, is obtained with a current density of 0.6–1.0 ampère from an 18 per cent. blue vitriol solution, and copper of great hardness and strength, but of little toughness, with 2 to 3 ampères, from a 20 per cent. solution.

For copper printing-plates, a 20 per cent. solution, compounded with 3 per cent. of sulphuric acid, and a current-density of 1.3 ampères, was found most suitable.

Many operators prefer as a bath a solution of pure blue vitriol of 22° Bé., without any addition of sulphuric acid. A good deposit is obtained in such a bath, but a tension of 2 to 2½

volts is required, while acidulated baths need only $\frac{3}{4}$ to $1\frac{1}{2}$ volts, according to the content of acid.

Very fine deposits have also been obtained in baths consisting of a blue vitriol solution of 21° Bé, brought up to 22° by the addition of sulphuric acid. This shows that it is not necessary to stick to a fixed unlimited composition of the baths, provided it is understood how to bring the current-condition into harmony with the composition.

According to the composition of the bath, a fixed minimum and maximum current-density correspond to it, which must not be exceeded if useful deposits are to be obtained. There is, however, a further difference according to whether the bath is at rest or in motion. v. Hübl obtained the following results:—

Composition of solution.	Minimum and maximum current-density per 15.5 square inches.	
	With solution at rest. Ampères.	With solution in gentle motion. Ampères.
15 per cent. blue vitriol, without sulphuric acid	2.6 to 3.9	3.9 to 5.2
15 per cent. blue vitriol, with 6 per cent. sulphuric acid . . .	1.5 " 2.3	2.3 " 3.0
20 per cent. blue vitriol, without sulphuric acid	3.4 " 5.1	5.1 " 6.8
20 per cent. blue vitriol, with 6 per cent. sulphuric acid . . .	2.0 " 3.0	3.0 " 4.0

Touching the addition of sulphuric acid, it was shown that no difference in the texture of the deposit is perceptible if the addition of acid varies between 2 and 8 per cent.

The preceding table shows that a copper bath in gentle motion can stand considerably higher current densities, and hence will work with correspondingly greater activity than a bath at rest. In the electrolytic refining of copper it was found that for the faultless deposition of copper the bath must be maintained entirely homogeneous in all its parts. When a copper bath is at rest and the depositing operation in progress, the upper layers of the bath become poorer in copper than the lower, while at the same time they contain more sulphuric acid. This difference in the composition of the upper and lower layers has the disadvantage

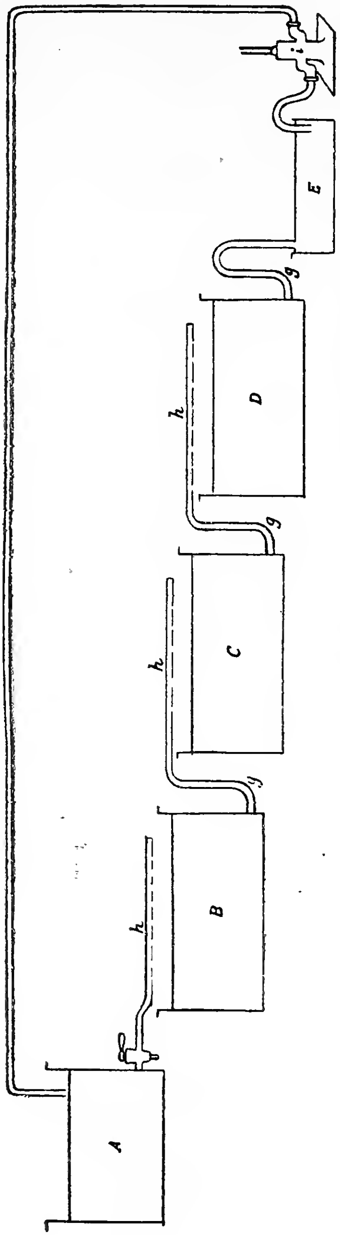


Fig. 122.

that the portions dipping into the layers richer in copper become more thickly coppered than those in the upper layers. Baths which are constantly in gentle motion show less inclination to the formation of knots and other rough excrescences, and hence the current-density may be greater than with solutions at rest resulting in the deposition being effected with greater rapidity. These experiences gathered in electro-metallurgical operations on a large scale, have been advantageously applied to galvanoplasty. The constant motion of the copper bath may be effected in various ways. Stirring by hand is frequently relied upon, but it is liable to be accidentally omitted, and being of necessity intermittent allows time for partial separation to occur between two consecutive stirrings. Mechanical agitation, which is more certain in its effects, may be applied by working a small screw propeller slowly at one end of the bath, or by blowing air into the solution constantly through a tube passing to the bottom of the vat, by means of a fan-blower or other arrangement.

Where many copper baths are in operation, the agitation of the bath may be effected as

follows: The baths are arranged in the form of steps; near the bottom each bath is provided with a leaden outlet-pipe (Fig. 122), which terminates over the next bath over a distributing gutter, or as a perforated pipe, *h*. From the last bath the copper solution flows into a reservoir, *E*, from which it is forced by means of a hard-rubber pump, *i*, into the reservoir, *A*, placed at a higher level; from *A* it again passes through the baths *B*, *C*, and *D*. A leaden steam coil may, if necessary, be placed in *A*, to increase the temperature if it should have become too low. Over *A* a wooden frame covered with felt may be placed; the copper solution flowing upon the frame and passing through the felt is thereby filtered.

Whatever motion is given to the bath it must be sufficiently vigorous to insure thorough mixture of the solution, but without disturbing the relative positions of anode and cathode, and the mechanism must be so applied that it in no way lessens the facilities for examining the progress of deposition.

Annealed sheets of pure copper are used as anodes; impure anodes introduce other metallic constituents into the bath, which might result in a brittle deposit. It is recommended daily to free the anodes from adhering residues by brushing, so as to decrease the collection of slime in the bath.

The anodes should present at least as large a surface as the cathodes; for flat moulds the distance between them and the anodes may be two to three inches, but has to be increased for deeper moulds. The copper withdrawn from the bath by deposition being only partially replaced by the anodes, the content of free acid will increase in consequence of the reduction of the content of copper. However, the copper wanting can be readily replaced by suspending bags filled with blue vitriol in the bath, while too large an excess of acid is removed by the addition of copper carbonate.

Determination of free acid.—The free acid is determined by titrating the copper solution with normal soda solution, congo paper being used as an indicator. Bring by means of a pipette, 10 cubic centimetres of the copper bath into a beaker glass, dilute with the same quantity of distilled water, and add drop by drop from a burette normal soda solution, stirring constantly, until

congo paper is no longer colored blue, when moistened with a drop of the solution in the beaker glass. The cubic centimetres of normal soda solution consumed multiplied by 4.9 give the number of grammes of sulphuric acid in the liter.

Suppose up to the appearance of the final reaction by means of congo paper, which indicates that all the free sulphuric acid has been saturated by the normal soda solution, 11.99 cubic centimetres of normal soda solution had been used for 10 cubic centimetres of copper bath, then one liter of the bath contains $11.9 \times 4.9 = 58.31$ grammes of sulphuric acid.

Determination of the content of copper according to Haën.—This method is based upon the conversion of blue vitriol and potassium iodide into copper iodide and free iodine. By determining the quantity of separated free iodine by titrating with solution of sodium hyposulphite of known content, the content of blue vitriol is found by simple calculation. The process is as follows: Bring 10 cubic centimetres of the copper bath into a measuring flask holding $\frac{1}{10}$ liter, neutralize the freed acid by the addition of dilute soda lye until a precipitate of bluish cupric hydrate, which does not disappear even with vigorous shaking, commences to separate. Now add, drop by drop, dilute sulphuric acid until the precipitate just dissolves; then fill the measuring flask up to the mark with distilled water, and mix by vigorous shaking. Of this solution bring 10 cubic centimetres by means of a pipette into a flask of 100 cubic centimetres' capacity and provided with a glass stopper; add 10 cubic centimetres of a 10 per cent. potassium iodide solution, dilute with some water, and allow the closed vessel to stand about 10 minutes. Now add from a burette, with constant stirring, a decinormal solution of sodium hyposulphite until starch-paper is no longer colored blue by a drop of the solution in the flask. Since 1 cubic centimetre of decinormal solution corresponds to 0.0249 gramme of blue vitriol (=0.0063 gramme of copper), the content of blue vitriol in one liter of the solution is found by multiplying the number of cubic centimetres of decinormal solution consumed by 24.9. For the correctness of the result it is necessary that the copper bath should be free from iron.

Suppose 7.2 cubic centimetres of decinormal solution of sodium

hyposulphite have been used, the bath would contain $7.2 \times 24.9 = 179.28$ grammes of blue vitriol.

If now by these two determinations, the content of free acid and of blue vitriol in the bath has been ascertained, a comparison with the contents originally present in preparing the bath will show how many grammes per liter the content of acid has increased, and how many grammes the content of copper has decreased. Then by a simple calculation it is found how much dry pure carbonate of copper has to be added per liter of solution to restore the original composition. For each gramme more of sulphuric acid than originally present, 1.26 grammes of carbonate of copper have to be added, and each gramme of carbonate of copper increases the content of blue vitriol 2.02 grammes per liter of bath. By reference to these data the operator is enabled to calculate whether the quantity of carbonate of copper added for the neutralization of the excess of free acid suffices to restore the original content of blue vitriol; or whether, and how much, blue vitriol per liter has to be added.

Preparation of moulds (matrices) in plastic material.—If a negative of the original for the production of copies is not to be made by direct deposition upon a metallic object, the negative has to be prepared by moulding the original in a plastic mass, which on hardening will retain the forms and lines of the design to the finest hatchings. Gutta-percha, wax (stearine, etc.), plaster of Paris, glue, and a few readily fusible metals are suitable materials for this purpose.

Since the galvanoplastic process as far as it applies to *electrotyping*, will next be considered, we first direct our attention to the preparation of moulds or matrices of gutta-percha and wax, the only materials suitable for this purpose, and which are generally used.

1. *Moulding in gutta-percha.*—For the reproduction of the fine lines of a wood-cut or copper-plate, pure gutta-percha freed by various cleansing processes from the woody fibres, earthy substances, etc., found in the crude product, is very suitable. Besides the requisite degree of purity, the gutta-percha should possess three other properties, viz., it must become *highly plastic*

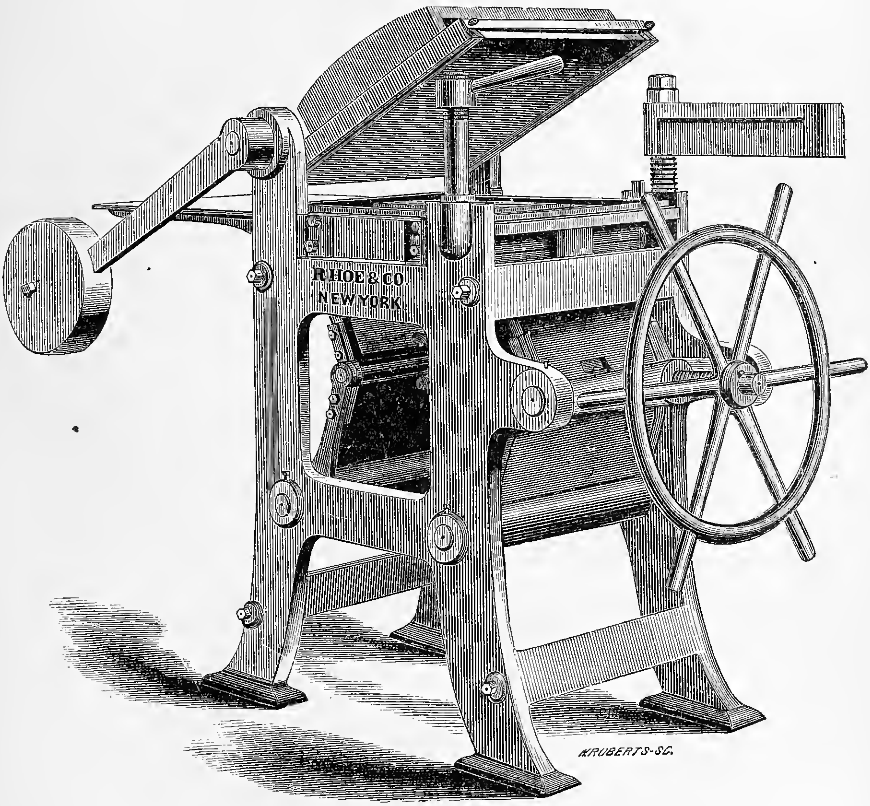
by heating, without, however, becoming *sticky*, and finally it should *rapidly harden.*

The most simple way of softening gutta-percha is to place it in water of 176° to 194° F. When thoroughly softened no hard lumps should be felt in kneading with the hands, in doing which the latter should be kept thoroughly moistened with water. A fragment corresponding to the size of the object to be moulded is then rolled into a plate about $\frac{1}{3}$ to $\frac{3}{4}$ inch thick. To facilitate the detachment of the mould after cooling, the surfaces of the objects to be moulded, as well as the side of the gutta-percha which is to receive the impression, should be well brushed with black-lead (plumbago or graphite). The black-leaded surfaces are then placed one upon the other, and after gently pressing the gutta-percha with the hand upon the original the whole is placed in the press. To stop the further movement of the press-plate and prevent injury to the mould by too strong a pressure, small iron blocks, somewhat higher than the frame containing the object to be moulded and the gutta-percha plate are placed on both sides of the frame. The screw of the press is then made to act until the press-plate touches the iron blocks; under this pressure the gutta-percha is allowed to cool and harden.

For making the impression of the form in the moulding composition, a moulding press is used which is capable of giving a gradual and powerful pressure. Fig. 123 represents a form of moulding press in common use, and known as the "toggle" press. It consists of a massive frame having a planed movable bed over which a head is swung on pivots and counter-balanced by a heavy-weight, as shown, so that it can be readily thrown up, leaving the bed exposed, the black-leaded type-form being placed on the bed. The well black-leaded case is attached by clamps to the movable head, or the form (also black-leaded) is laid face down on the case, and the head is then turned down and held in place by the swinging bar (shown turned back in the cut). All being ready, the toggle-pressure is put on by means of the hand-wheel and screw, the result being to raise the bed of the press with an enormous pressure, causing the face of the type-form to impress itself into the exposed moulding surface.

Fig. 124 represents a form of "hydraulic press" less commonly used than that just described. It is provided with projecting

Fig. 123.

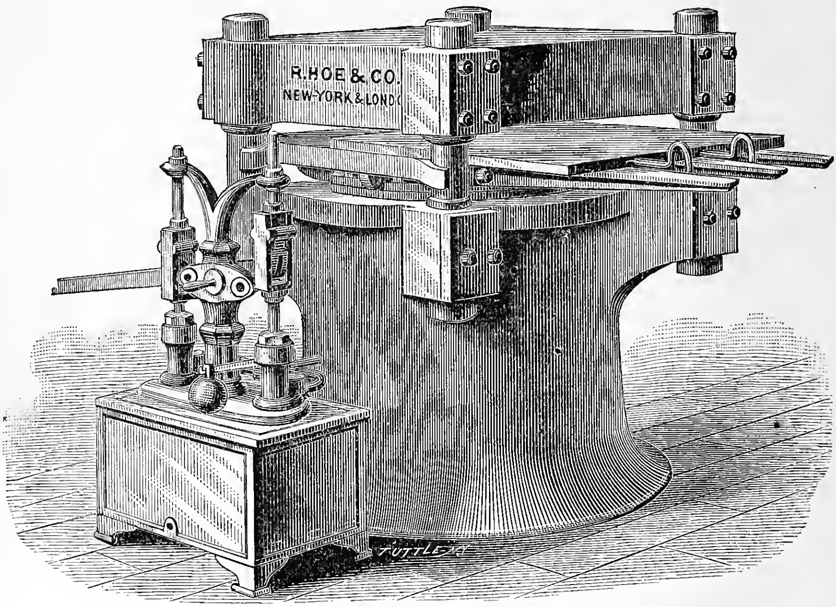


rails and sliding plate, on which the form and case are arranged before being placed in the press. The pump, which is worked by hand, is supported by a frame-work on the cistern below the cylinder, and is furnished with a graduated adjustable safety-valve to give any desired pressure.

2. *Moulding in wax* (*stearine*).—Beeswax is a very useful material for preparing moulds, but, like stearine, it is according to the temperature now softer and now harder, which must be taken into consideration. In the cold, pure beeswax is quite brittle and

apt to become full of fissures in pressing. To decrease the brittleness certain additions are made to the wax, Urquart recommend-

Fig. 124.



ing the following mixture, which is frequently used in England: Beeswax 85 parts by weight, Venice turpentine 13, black-lead finely pulverized 2.

According to Volkmer, a good mixture is obtained by melting together 70 parts of wax and 30 of stearine. Watt prefers a mixture consisting of 70 parts of wax, 26 of stearine, and 4 of litharge or flake-white. G. L. v. Kress recommends the following mixture: White wax 42.32 ozs., stearine 14.11 to 21.16 ozs., tallow 1058 ozs., graphite 1.76 ozs. First melt the asphalt over a moderate fire, then add the wax, stearine, and tallow, and when these are melted, the graphite; stir until the mixture begins to congeal.

To prepare the wax mould pour the melted composition into flat metallic trays provided with loops for suspension in the bath. When the composition is nearly set remove any bubbles of air or

impurities from the surface with blotting-paper. After black-leading the surface press the original, also black-leaded, upon the composition and submit the whole to pressure until cold. When the black-leading has been carefully done there is no difficulty in detaching the original after cooling; many operators slightly oil the surface of the original instead of black-leading.

When the mould of gutta-percha or wax has been properly made, it is thoroughly black-leaded in order to give it a conducting surface upon which the electro-deposition of the copper may take place. Black-leading must be very thorough so that the black-lead penetrates into every line and letter of the mould, otherwise the copper deposited on the surface will be an imperfect copy of the original, and it will be useless to place the mould in the bath. The black-lead used in every stage of the electrotyping process must be of the purest description and in the most minute state of division. The best material for the purpose is prepared from the purest selected Ceylon graphite, which is ground by rolling with heavy iron balls until it is reduced to a dead-black, impalpable powder.

Black-leading the moulds is performed either by hand or more commonly by machines.

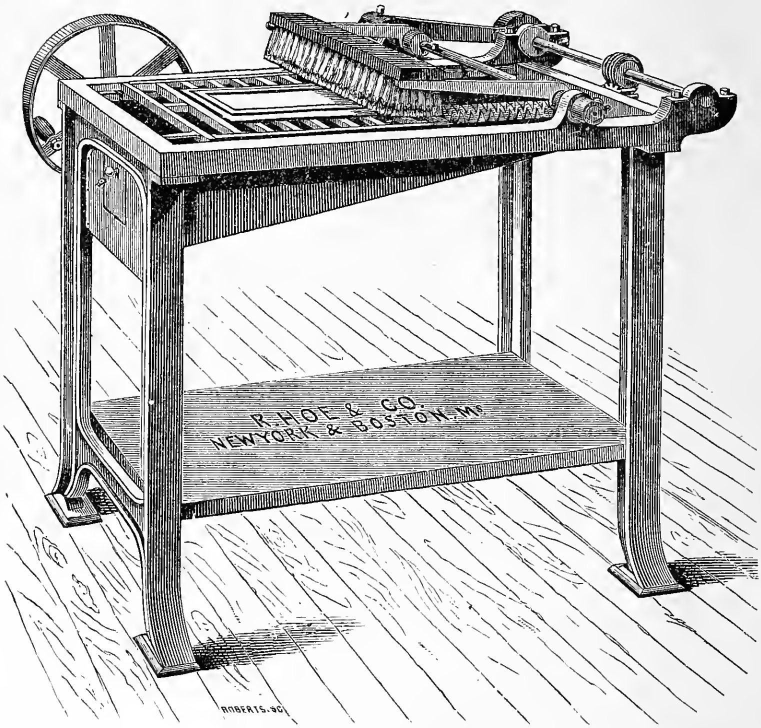
Fig. 125 shows one of these machines with its cover removed to exhibit its construction. It has a travelling carriage holding one or more forms, which passes backward and forward, under a laterally vibrating brush. Beneath the machine is placed an apron which catches the powder, which is again used.

Another construction of a black-leading machine is shown in Fig. 126, the details of which will be understood without lengthy description. The moulds are placed upon the slowly revolving, horizontal wheel upon which the brush moves rapidly up and down with a vertical, and at the same time laterally, vibrating motion. The black-leading space being closed air-tight, scattering of black-lead dust is entirely prevented, the excess of black-lead collecting in a vessel placed in the pedestal.

On account of the dirt and dust caused by the dry process of black-leading, some electrotypers prefer the wet process invented by Mr. Silas P. Knight, of New York. This process is designed to work more quickly and neatly, producing moulds that are

thinly, evenly, and perfectly covered. The moulds are placed upon a shelf in a suitable receptacle, and a rotary pump forces an

Fig. 125.

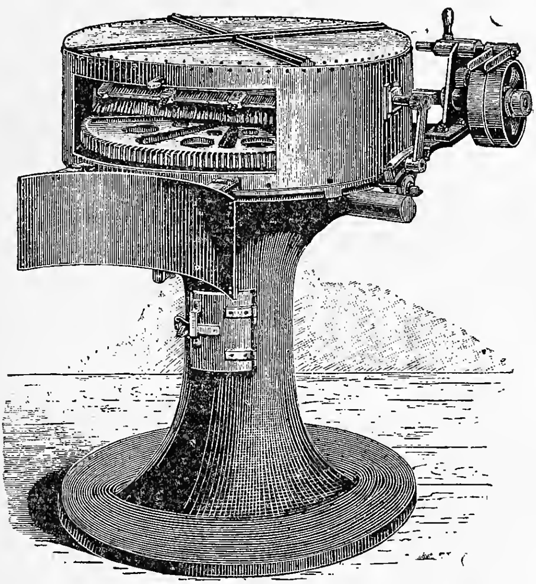


emulsion of graphite and water over their surfaces through a travelling fine-rose nozzle. This process is pronounced to be rapid, efficient, neat, and economical.

With very deep forms of type, it is sometimes of advantage to first coat the black-leaded surface with copper, in order to obtain a uniform deposit in the bath. The process is as follows: Pour alcohol over the black-leaded form, let it run off and then place the form horizontally over a water trough. Now pour over the form blue vitriol solution of 15° to 16° Bé., dust upon it from a pepper-box some impalpably fine iron filings and brush the mixture over the whole surface, which thus becomes coated with a

thin, bright, adherent film of copper. Should any portion of the surface after such treatment remain uncoppered, the operation is

Fig. 126.



repeated. The excess of copper is washed off and the form, after being provided with the necessary conducting wires, is ready for the bath.

Gilt or silvered black-lead is also sometimes used for very deep forms. It is, however, cheaper to mix the black-lead with $\frac{1}{3}$ its weight of finest white bronze powder from finely divided tin. When forms thus black-leaded are brought into the copper bath, the particles of tin become coated with copper, also causing a deposit upon the black-lead particles in contact with them.

After black-leading the workman takes one or several stout copper wires, the ends of which, after thorough cleansing, he heats for an instant, and imbeds them in the wax on the side of the mould. The surface of this wire is carefully exposed, and by way of precaution the place is rubbed with black-lead with the finger to restore the black-lead surface that may have been disturbed. Trifling as this circumstance of exposing the imbedded

wire may appear, the galvanic deposit of the copper on the face of the mould would be impossible were it neglected, as the mass of wax being a non-conductor of electricity, a galvanic current could not otherwise be established. The exposure of the wire, therefore, is essential in order that the surface of the mould may be rendered properly conductive to insure the uniform deposition of copper upon it. To confine the deposit of copper where it is actually desired, and to prevent it from unnecessarily spreading over the edges of the mould, a tool called the "building iron" is heated and run over the mould so as to destroy the continuity of the black-lead surface, save where the deposit of copper is wanted.

In order that the deposition of copper may be as nearly uniform in thickness as possible over the entire surface of the mould, it becomes necessary, where a large surface is to be coated, to provide as much metallic surface as possible on which the deposit of copper may commence and spread. One method of accomplishing this, is to attach one or more pieces of metal to the wax on the edges of the mould, and connect them with the slinging wires by good metallic connections.

A very practical device in this connection is the "electric-connection gripper" of Messrs. R. Hoe & Co., of New York. This arrangement is designed to hold and sustain the moulding case, and at the same time to make an electric connection with the prepared conducting face of the mould only; consequently, leaving the metal case itself entirely out of the current, so that no copper can be deposited on it.

Gutta-percha being specifically lighter than water, moulds of this material have to be provided with a piece of heated lead stuck to the back to prevent them from floating, and to force them to occupy a perpendicular position opposite to the anodes.

The moulds are suspended in the bath in the same manner as in other galvanic processes, special care being had that their surfaces hang parallel to the anodes, so that all portions may receive a uniform deposit. Before placing the mould in the bath, pour over it, while in a horizontal position, a mixture of equal parts of alcohol and water; by this means, a uniform moistening of the

mould in the bath is attained, and the settlement of air-bubbles on it prevented.

For the production of a dense, coherent, and elastic deposit in the acid-copper bath, the chief requisite is to have the current-strength in the correct proportion to the surface to be coated, this applying to deposition with the single-cell apparatus, as well as with an external source of current.

The stronger the sulphuric acid in the clay cells of the simple apparatus is, with the greater rapidity it acts upon the zinc plates, and the more quickly is the copper deposited upon the moulds. If the zinc surface of the clay cells is very large in proportion to the surface of the moulds, the deposition of copper also takes place with correspondingly greater rapidity. However, a rapid deposition of copper is to be avoided, if deposits possessing the above-mentioned desirable properties are to be obtained, because a deposit forced too much, turns out incoherent, lacking in density, is frequently blistered, and, with too strong action, is even pulverulent. The color of the deposit furnishes a certain criterion for its quality; a red-brown color indicating an unsuitable deposit, and a beautiful rose color a good serviceable one.

One part of concentrated sulphuric acid of 66° Bé. to 30 of water has formerly been given as the proper proportions for the dilute acid used for filling the clay cells, provided the zinc surface be about the same as that of the moulds. If the zinc surface is smaller than that of the moulds, stronger acid may be used; but if it is larger, the acid will have to be more dilute. The correct concentration of the acid in the clay cells may be readily determined by the progressive result of the deposit and its color. Deep moulds require a stronger current, and hence acid of greater strength than flat moulds; however, if after such deep moulds are provided with a preliminary deposit, the current proves too strong for the correct progress of the operation, its action may be weakened by either diluting the acid in the clay cells with water, or by taking out a few zinc plates, or by hanging a few copper sheets upon the object-rods, or suspending more moulds.

For the deposition of copper with a separate source of current (battery or dynamo), the same that has been said above applies as

regards the current-strength, which must be brought to a suitable degree by the resistance board. The most suitable current-density for the production of a good deposit is 1.5 to 2 ampères per $15\frac{1}{2}$ square inches of surface of moulds for baths for depositions with a separate source of current, given on page 310, if at rest, and 2 to 3 ampères if in motion.

Since even for deeper moulds a tension of 1.5 volts suffices, if the bath is acidulated, the more powerful Bunsen elements will have to be coupled alongside one another; but two of the weaker Daniell or Lallande elements one after the other, and of such groups, as many as are required, will have to be coupled alongside one another for quantity of current (see page 18), to make the active zinc surface nearly equal to that of the moulds. However, for flat moulds coupling the separate weaker elements alongside one another is also sufficient. When the moulds are coated with copper on every side, and also the deeper portions, the current is weakened if a copper deposit of pulverulent or coarse-grained structure and of a dark color should appear on the edges of the moulds, and it is feared that the deposit upon the design or type might also turn out pulverulent. The current, however, should only be sufficiently weakened to prevent a further progress of the dark deposit on the edges towards the interior of the surface of the mould. If, however, by too strong a current the separation of a pulverulent deposit upon the design has already taken place, the deposit may generally be saved, if the fact is noticed in time, and the current correspondingly weakened, as the layers are firmly united by the coherent copper then deposited.

The current of the dynamo-machine must also be sufficiently weakened by the resistance board in front of the bath, or by that of the machine to guarantee the good quality of the deposit. For deeper moulds the tension for covering may amount to 1 or 1.5 volts, and for very deep and steep moulds to 1.5 or 2 volts. But when the moulds are completely covered the current is reduced to about 0.75 volt,* and the operation finished with this tension.

The average time required for the production of a sufficiently heavy deposit with a dynamo-machine is from 7 to 8 hours. In

* These current-strengths refer to formulæ I. and II. given on page 310.

this time the deposit acquires a thickness of about $\frac{1}{3}$ millimetre (0.013 inch), which corresponds to a weight of about 25 grammes (14.11 drachms) of copper per $15\frac{1}{2}$ square inches.

Now, since it frequently happens that an electrotype has to be finished and delivered in a hurry, the work may have to be continued during the night; but as it may not be desirable to have the dynamo running, either a cell apparatus or accumulators have to be employed. In using a cell apparatus, it is advisable to first quickly coat the moulds by the current of the dynamo, and then finish the deposit in the apparatus.

In modern times accumulators have been successfully used for the same purpose.

A detailed description of the accumulators and directions for their treatment may here be omitted, they being furnished by the manufacturers of the various systems. Each accumulator consists of a number of alternately positive and negative lead plates immersed in a vessel filled with dilute sulphuric acid. By conducting the current of a dynamo-machine into the accumulator so that the positive current passes into the positive plates, and the negative current into the negative plates, lead peroxide is formed upon and in the porous positive plates by the co-operation of the sulphuric acid and the oxygen appearing on the positive pole, and the greater the quantity of lead peroxide thus formed, the more electricity is stored in the accumulators. These operations are called *charging* the accumulator. By interrupting the introduction of a current and closing the circuit of the positive and negative plate systems by the introduction of electrodes in an electrolyte (galvanic bath), a current is developed whereby the lead peroxide of the positive plates which has been formed is reduced to lead, while the negative plates are oxidized to lead peroxide. This process is termed *discharging*. The chemical processes appearing thereby are of more complicated nature than here given, but are omitted so as to render comprehension of the process less difficult. The directions for charging and discharging the accumulator must be strictly followed, and require great attention, as charging with too strong a current, or a too abundant discharge may cause the rapid destruction of the plates. The

charging is best done during the day with a special small dynamo-machine.

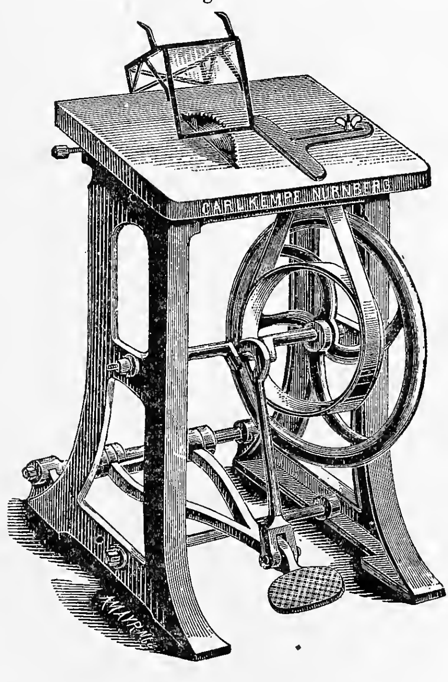
Detaching the deposit from the mould.—When the mould has received a suitable deposit, it is taken from the bath, rinsed in water, and all edges which might obstruct the detachment of the deposit from the mould are removed with a knife. From gutta-percha moulds the deposit is gradually lifted by inserting under one corner a flat horn plate or a thin dull brass blade and applying a very moderate pressure; particles of gutta-percha which may remain adhering are carefully burnt off over a flame. Wax moulds are placed in an inclined position, and a stream of hot water is poured over the copper surface, by which means the wax is sufficiently softened to allow the shell of copper to be stripped off. This may be done by taking hold of one corner of the shell and quickly lifting it as the hot water flows over it. In removing the shell care should be taken to keep it straight, as otherwise it will be difficult to back and finish it properly.

Backing the deposit or shell.—The tinning of the back of the shell is the next operation, and has for its object to strengthen the union between the shell and the backing metal. For this purpose the back of the shell is cleansed by brushing with "soldering-fluid," made by allowing muriatic acid to take up as much zinc as it will dissolve, and diluting with about $\frac{1}{3}$ of water, to which some sal ammoniac is sometimes added. Then the shell, face down, is heated by laying it upon an iron soldering plate, floated on a bath of melted stereotype metal, and, when hot enough, melted solder (half lead and half tin) is poured over the back, which gives it a clean, bright metallic covering. Or, the shell is placed downward in the backing-pan, brushed over the back with the soldering fluid, alloyed tinfoil spread over it, and the pan floated on the hot backing metal until the foil melts and completely covers the shell. When the foil is melted the backing pan is swung on to a levelling stand, and the melted backing metal is carefully poured on the back of the shell from an iron ladle, commencing at one of the corners and gradually running over the surface until it is covered with a backing of sufficient thickness. Another method is as follows: After tinning the shell it is allowed to take the

temperature of the backing metal on the floating iron plate. The plate is then removed from the melted metal, supported in a level position on a table having projecting iron pins on which it is rested, and the melted stereotype metal is carefully ladled to the proper thickness on the back of the tinned shell. This process is called "backing." The thickness of the metal-backing is about an eighth of an inch. A good composition for backing metal consists of lead 90 parts, tin 5, and antimony 5.

Finishing.—For this purpose the plates go first to the saw table (Fig. 127), for the removal of the rough edges by means of a

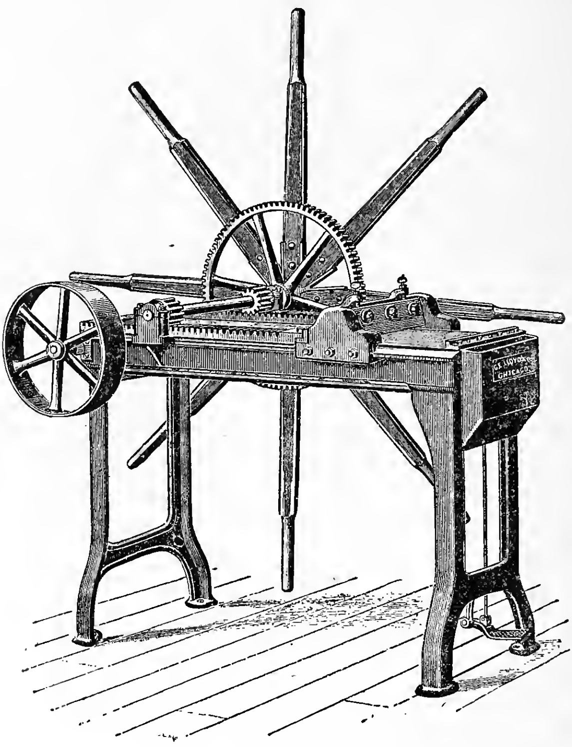
Fig. 127.



circular saw. The plates are then shaved to take off any roughness from the back and make them of even thickness. In large establishments this portion of the work, which is very laborious, is done with a power planing or shaving machine, types of which are shown in Figs. 128 and 129, Fig. 128 being a shaving machine

with steam one way, and Fig. 129 one with steam both ways. The flatness of the plates is then tested with a straight edge and

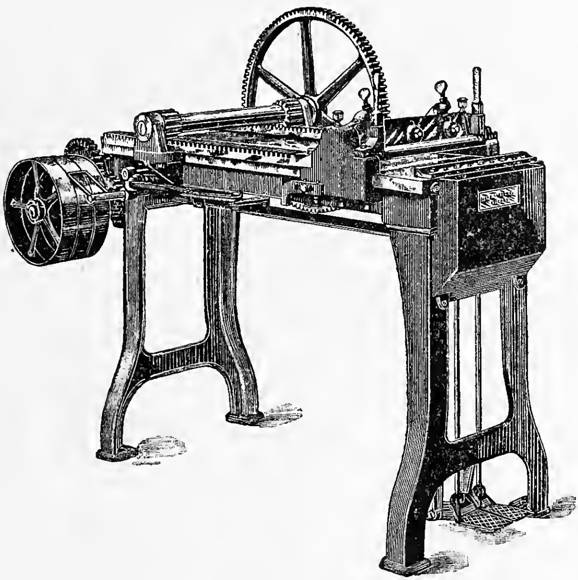
Fig. 128.



any unevenness rectified by gentle blows with a polished hammer, taking every care that the face be not damaged. The plate then passes to the hand shaving machine, where the back is shaved down to the proper thickness, smooth and level. The edges of the plate are then planed down square and to a proper size, and finally the plates are mounted on wood type-high. Book-work is generally not mounted on wood, the plates being left unmounted and finished with bevelled edges, by which they are secured on suitable plate-blocks of wood or iron supplied with gripping pieces, which hold them firmly at the proper height and enable them to be properly locked up.

Finally, it remains to say a few words about the process by which a copy may be directly made from a metallic surface with-

Fig. 129.



out the interposition of wax or gutta-percha. If the metallic surface to be moulded were free from grease and oxide, the deposit would adhere so firmly as to render its separation without injury almost impossible. Hence, the metallic original must first undergo special preparation, so as to bring it into a condition favorable to the detachment of the deposit. This is done by thoroughly rubbing the original with an oily rag, or, still better, by lightly silvering it and exposing the silvering for a few minutes to an atmosphere of sulphuretted hydrogen, whereby sulphide of silver is formed, which is a good conductor, but prevents the adherence of the deposit to the original. For the purpose of silvering, free the surface of the metallic original (of brass, copper, or bronze) from grease, and pickle it by washing with dilute potassium cyanide solution (1 part potassium cyanide to 20 water). Then brush it over with a solution of $4\frac{1}{2}$ drachms of nitrate of silver

and 1 oz. 6 drachms of potassium cyanide (98 per cent.) in 1 quart of water; or, still better, immerse the original for a few seconds in this bath, until the surface is uniformly coated with a film of silver. The production of the layer of sulphide of silver is effected according to the process described later on (p. 338). The negative thus obtained is also silvered, made yellow with sulphuretted hydrogen, and a deposit of copper is then made, which represents an exact copy of the original. Instead of sulphurizing the silvering with sulphuretted hydrogen, it may also be iodized by washing with dilute solution of iodine in alcohol. The washed plate, prior to bringing it into the copper bath, is for some time exposed to the light.

To prevent the separation of copper on the back of the metallic original to be copied, it is coated with asphalt lacquer, which must be thoroughly dry before bringing into the bath. When the deposit of copper is of sufficient thickness, the plate is taken from the bath, rinsed in water, and dried. The edges are then trimmed off by filing or cutting to facilitate the separation of the shell from the original.

Of course, only metals which are not attacked by the acid copper solution can be directly brought into the bath. Steel plates must therefore first be thickly coppered in the alkaline copper bath (p. 194), and even this precaution does not always protect the plate from corrosion. It is therefore better to produce in a silver bath (formula I., p. 213) a copy in silver of sufficient thickness to allow of the separation of both plates. The silver plate is iodized, and from it a copy in copper is made by the galvanoplastic process. The copper plate thus obtained is an exact copy of the original, and after previous silvering the desired number of copies may be made from it.

Electro-etching.—The lines produced by the ordinary process of etching actually represent, when viewed under the microscope, a continuous series of irregular depressions and small cavities, and when some depth is required they are apt to be corroded underneath, and to increase so much in width that the plates are frequently spoiled. None of these objections applies to the galvanic process of etching, which is the invention of Thomas Spencer. Each line, when viewed under the microscope, represents a perfect

furrow, and is just rough enough—for instance, in the preparation of printing plates—to hold the printing ink. Lines of considerable depth may be produced without the danger of extending in width or corroding underneath. The corners of the intersection of two lines are as sharp as if the lines were engraved. A chief requisite for electro-etching is a good etching ground, since it may frequently happen that the latter may answer very well for the ordinary process, but is not capable of offering sufficient resistance to the electric current. A great advantage in electro-etching is that the solvent is always of the same strength, and, therefore, constant in its action, and that there is no evolution of acid vapors which are injurious to the respiratory organs.

The operation of electro-etching is conducted as follows: A conducting wire is soldered with tin solder to the object, and the latter is then coated with the etching ground. The design is then traced with a graver, taking care that the tool lays bare the metal in all the lines. The object thus prepared is connected with the positive pole and suspended in the bath, while a plate of the same metal as the object is secured to the negative pole. The bath consists of a dilute acid corresponding to the metal of the object. For silver dilute nitric acid is used; for gold and platinum, water acidulated with aqua regia; for copper, brass, and zinc, water acidulated with sulphuric acid; and for tin, water acidulated with hydrochloric acid. Baths containing the metal to be etched in solution, however, work better than acids diluted with water. Thus, for gold and platinum, chloride of gold and platinic chloride are used; for silver, solution of nitrate of silver; for copper and brass, solution of blue vitriol; for iron and steel, solution of green vitriol, or of ammonium chloride, or a combination of both; for zinc, solution of white vitriol or of chloride of zinc, etc. There are besides various metallic salts suitable for etching by themselves or in combination with the above-named salts.

As *etching ground* various compositions may be employed, it being, however, best to use, if possible, one which can be readily removed. A mixture of equal parts of asphalt and copal varnish forms a good etching ground; also a composition obtained by melting together asphalt $2\frac{1}{2}$ parts, wax 2, rosin 1, and black pitch 2. However, the following composition, which resists 25 per

cent. nitric acid, is to be preferred. It is prepared as follows: Melt yellow wax 4 parts, Syrian asphalt 4, black pitch 1, and white Burgundy pitch 1. When the mixture boils gradually add, with constant stirring, 4 parts more of pulverized Syrian asphalt. Continue boiling until a sample poured upon a stone and allowed to cool breaks in bending. Then pour the mixture into cold water and shape it into small balls, which for use are dissolved in oil of turpentine.

Since the current-strength is under perfect control, the etching may be carried to any depth desired. Some portions may be less etched than others by taking the plate from the bath, and, after washing and drying, coating the portions which are not to be further etched with lacquer, and returning the plate to the bath.

Printing plates in relief may in this manner be prepared by slightly etching the bared design of a copper-plate in the galvanoplastic copper bath, and then bringing the plate as object in contact with the negative pole, while a plate of chemically pure copper serves as anode. The deposited copper unites firmly with the rough copper of the etched plates, and after removing the etching-ground with benzine or oil of turpentine the design appears in relief.

Heliography.—By this term are understood several methods of printing, in which plates of asphalt, chrome-gelatine, etc., produced by exposure to light, are used. For our purposes only the method is of interest by which from the negative, produced by the action of light, a galvanoplastic reproduction—printing plates in high and low relief—in metal is made. The heliographic process invented by Pretsch and improved by Scamoni, consists in taking by photography a good negative of the engraving or other object to be reproduced, developing with green vitriol, reinforcing with pyrogallic acid and silver solution, and then fixing with sodium hyposulphite solution in the same manner as customary for photographic negatives. A further reinforcement with chloride of mercury solution then takes place until the layer appears light gray. Now wash thoroughly and intensely blacken the light portions by pouring upon them dilute potassium cyanide solution. As in the photographic process, the solutions must be applied in abundance and without stopping, as otherwise streaks

and stains are formed. After washing, the plate is dried, further reinforced, and finally coated with colorless negative varnish. From this negative a positive collodion picture is taken, which is in the same manner developed, reinforced, and fixed, the reinforcement with pyrogallic acid being continued until the picture is quite perceptibly raised. After careful washing, pour upon the plate quite concentrated chloride of mercury solution, which has to be frequently renewed, until the picture, at first deep black, acquires a nearly white color, and the lines are perceptibly strengthened. Now wash with distilled water, next with dilute potassium iodide solution, and finally with ammoniacal water, whereby the picture acquires first a greenish, then a brown, and finally a violet-brown color. After draining, the plate may progressively be treated with solutions of platinum chloride, gold chloride, green vitriol, and pyrogallic acid, the latter exerting a solidifying effect upon the pulverulent metallic deposits. The metallic relief is now ready; the layer is slowly dried over alcohol, and the plate, when nearly cold, quickly coated with a thin rosin varnish, which, after momentary drying, remains sufficiently sticky to retain a thin layer of black lead, which is applied with a tuft of cotton. The edge of the plate is finally surrounded with wax, and, after being wired, the plate is brought into the galvanoplastic copper bath to be reproduced.

Galvanoplastic reproduction of busts, vases, etc.—For this purpose an entirely different process of preparing the moulds than that described for electrotyping is required, the material for moulding depending on the nature of the original. Besides gutta-percha and wax, readily fusible metals, plaster of Paris, and glue will have to be considered. If the original bears heating to about 230° F., a copy in one of the readily fusible alloys given later on may be made; if it will stand heat and pressure, it is best to mould in gutta-percha; but if neither heat nor pressure can be applied, the moulds will have to be executed in plaster of Paris or in glue. The manner of moulding and the material to be chosen furthermore depend on whether surfaces in high relief or round plastic bodies are to be copied, whether projecting portions are undercut, and whether the mould can be directly detached, or,

if this is not the case, whether the original has to be dissected and moulded in separate parts.

Regarding the practice of moulding, the reader is referred to special works on that subject; only the main points for the most frequently occurring reproductions will here be given.

Surfaces in relief and not undercut are readily moulded in an elastic mass such as gutta-percha or wax; however, undercut reliefs and especially round plastic objects mostly require a plaster-of-Paris mould and are generally dissected; the dissection being of course not carried further than absolutely necessary, because the separate parts must be united by a soldering seam which requires careful work, and the seam itself must be worked over and made invisible. Hence the section should as much as possible be made through smooth surfaces, edges, etc., where the subsequent union by a soldering seam will prove least troublesome, while cutting through ornaments or through portions, the accurate reproduction of which is of the utmost importance, should be avoided. Heads and busts are always executed in a core mould and in portions unless the entire figure is to be deposited in one piece in a closed mould. The section is made either through the centre line of the head through the nose, which, however, makes the subsequent union very troublesome, if the copy is to be an exact reproduction of the original, or the mould is divided from ear to ear, which has the disadvantage that the deepest part of the mould corresponding to the nose receives the thinnest deposit. It has, therefore, been proposed to make two cuts so that three portions are formed; one cut from one ear at the commencement of the growth of hair to the other ear; and the second cut from one ear in a downward direction below the lower jaw in the joint of the head and neck, through this joint below the chin, and then upwards to the other ear, and in front of it to where the hair begins. In bearded male heads the cut follows the contour of the beard and not the joint on the neck behind the beard.

To mould round articles in gutta-percha, the softened gutta-percha is kneaded with wet hands upon the oiled original, or, in order to avoid that some portions receive a stronger pressure than others, and to insure a layer of gutta-percha of uniform thickness upon all portions, the moulding may also be executed in a ring

or frame of iron or zinc under a press. For the rest, all that has been said in regard to moulding in gutta-percha on p. 315 is also applicable.

The following *metallic alloys* have been proposed for the preparation of moulds:—

I. Lead 2 parts, tin 3, bismuth 5; fusible at 212° F.

II. Lead 5, tin 3, bismuth 8; fusible at 185° F.

III. Lead 2, tin 2, bismuth 5, mercury 1; fusible at 158° F.

IV. Lead 5, tin 3, bismuth 5, mercury 2; fusible at 127.5° F.

The advantage of metallic moulds consists in that the metal is a good conductor of electricity, in consequence of which heavy deposits of greater uniformity can be produced than with non-metallic moulds which have been made conductive by black lead. Nevertheless, they are but seldom employed on account of the crystalline structure of the alloys and the difficulty of avoiding the presence of air bubbles. Böttger claims that a mixture of lead 8 parts, tin 3, and bismuth 8, which is fusible at 227° F., shows a less coarse-grained structure.

Fusible alloys containing mercury should not be used for taking casts of metallic objects—iron excepted—as these will amalgamate with the mercury and be injured. Moreover, copper deposits obtained upon such alloys are very brittle, which is due to the combination of the mercury with the deposited copper.

For moulding with metallic alloys place the oiled object at the bottom of a flat vessel and pour the liquid metal upon it; or pour the liquid metal into a box, remove the layer of oxide with a piece of stout paper, and when the metal is just beginning to congeal firmly press the object in it.

Plaster of Paris is used for making casts of portions from originals which are so strongly undercut that a mould consisting of one piece could not be well detached from them. For taking casts from metallic coins and medals or from small plaster reliefs, it is a very convenient material. The mode of procedure is as follows: After the original model, say a medal, has been thoroughly soaped or black-leaded, wrap round the rim a piece of sufficiently stout paper or thin lead foil, and bind it in such a manner by means of sealing-wax that the face of the medal is at the bottom of the receptacle thus formed. Then place the whole to a certain

depth in a layer of fine sand, which prevents the escape of the semi-fluid plaster of Paris between the rim of the medal and the paper. Now mix plaster of Paris with water to a thin paste, take up a small quantity of this paste with a pencil or brush and spread it in a thin film carefully and smoothly over the face of the medal, then pour on the remainder of the paste up to a proper height and allow it to set. After a few minutes the plaster heats and solidifies. Then remove the surrounding paper, scrape off with a knife what has run between the paper and the rim of the medal, and carefully separate the plaster cast from the model. If instead of applying the first layer with a brush, the whole of the plaster were run at once into the receptacle, there would be great risk of imprisoning air bubbles between the model and the mould, which would consequently be worthless. The mould is finally made impervious and conductive according to one of the methods to be described later on.

The moulding in plaster of Paris in portions, when casts from large plastic objects with undercut surfaces and reliefs are to be taken, is troublesome work, because each separate mould must not only be so that it can be readily separated without injury to the original, but must also fit closely to its neighbors. Hence thought and judgment are required to see of which parts separate moulds are to be made, or, in other words, in how many parts the mould is to be made. After determining on the plan of the work, the mode of procedure is as follows: Oil a portion of the object, if it consists of metal, or soap it, if of plaster of Paris, marble, wood, etc., and apply by means of a brush a thinly-fluid paste of plaster of Paris, taking care that no air bubbles are formed by the strokes of the brush. When this thin coat is hard, continue the application of plaster of Paris with a horn spatula until the coat has acquired a thickness of $\frac{3}{4}$ to 1 inch, and allow it to harden. Then separate the mould, and after cutting or sawing the edges square and smooth, replace it upon the portion of the original model corresponding to it. Now oil or soap the neighboring portions of the model, and at the same time the smooth edges of the first mould which come in contact with the mould now to be made, and then proceed to make the second mould in precisely the same manner as the first. When the second mould is hard, trim the

edges and replace it upon the model; the same process being continued until the entire original model is reproduced in moulds well fitting together. To prevent the finished moulds from falling off, and to retain them in a firm position upon the original model, they are tied with lead wire or secured with catches of brass wire or sheet. When the moulds of the larger portion of the model, for instance, one-half of a statue, are finished, the so-called case or shell is made, *i. e.*, the backs of all the moulds are coated with a layer of plaster of Paris which holds them together. This case is best made not too thin in order to attain a better resisting power.

The entire model having been cast in the manner above described, and the moulds provided with the case, the whole is completely dried in an oven.

The next operation is to make the plaster of Paris impervious to fluids, as otherwise, by the moulds absorbing the acid copper bath, copper would be deposited in the pores of the plaster and the moulds be spoiled, while the copy would turn out rough instead of having the smooth exterior of the model. To render plaster of Paris and other porous substances impervious, they are saturated with wax or stearine or covered with a coat of varnish, the latter process being generally employed for large moulds. Apply a coat of thick linseed oil varnish to the face of the mould, and, after drying, repeat the process until the mould is thought to be sufficiently impervious. Rendering the mould impervious with wax or stearine is a better and more complete method. For this purpose cut a groove in the rim of the mould, place in the groove a brass wire and twist the ends, which must be long enough to hold the mould by. The mould, having been previously dried, is then dipped into a bath of wax or stearine kept at a temperature of from 180° to 212° F., and a number of air bubbles will escape from the mould to the surface. When the production of air bubbles is considerably diminished, remove the mould from the bath, and lay it face up in a drying oven, whereby the melting wax in consequence of its gravity oozes down, and the face of the mould is freed from an excess of wax. Whenever possible, submerging the entire mould should be avoided and the operation be conducted as follows: Place the heated mould in a vat filled with

melted wax or stearine, so that the face does not come in contact with the wax, but absorbs wax by capillarity from the back.

The moulds thus coated with varnish or saturated with wax are now made conductive with black-lead, the operation being the same as that mentioned on p. 319. For many undercut or deep portions black-leading is, however, not sufficient, and recourse must be had to making the moulds conductive or *metallizing* them *by the wet way.*

Metallization by the wet way.—This method consists in the deposition of certain metallic salts upon the moulds and their reduction to metal or conversion to conductive sulphur combinations. The process in general use is as follows: Apply with a brush upon the mould a not too concentrated solution of nitrate of silver in a mixture of equal parts of distilled water and 90 per cent. alcohol. When the coat is dry expose it in a closed box to an atmosphere of sulphuretted hydrogen; the latter converts the nitrate of silver into sulphide of silver, which is a good conductor of the current. For the production of the sulphuretted hydrogen place in the box, which contains the mould to be metallized, a porcelain plate or dish filled with dilute sulphuric acid (1 acid to 8 water), and add five or six pieces of iron pyrites the size of a hazelnut. The development of the gas begins immediately, and the box should be closed with a well-fitting cover to prevent inhaling the poisonous gas; if possible, the work should be done in the open air or under a well-drawing chimney. The formation of the layer of sulphide of silver requires but a few minutes, and if not many moulds have to be successively treated, the acid is poured off from the iron pyrites and clean water poured upon the latter so as not to cause useless development of gas.

It has also been recommended to decompose the silver salt by vapors of phosphorus and to convert it into phosphide of silver, a solution of phosphorus in bisulphide of carbon being used for the purpose. The layer of silver salt is moistened with the solution or exposed to its vapors. This method possesses, however, no advantage over the preceding, because, on the one hand, the phosphorous solution takes fire spontaneously, and, on the other, the odor of the bisulphide of carbon is still more offensive than that of sulphuretted hydrogen.

A somewhat *modified method* is given by Parkes as follows: Three solutions, A, B, C, are required. Solution A is prepared by dissolving 0.5 part of caoutchouc cut up in fine pieces in 10 parts of bisulphide of carbon and adding 4 parts of melted wax; stir thoroughly, then add a solution of 5 parts of phosphorus in 60 of bisulphide of carbon together with 5 of oil of turpentine and 4 of pulverized asphalt; then thoroughly shake this mixture, A. Solution B consists of 2 parts by weight of nitrate of silver in 600 of water; and solution C of 10 parts of chloride of gold in 600 of water. The mould to be metallized is first provided with wires and then brushed over with, or immersed in, solution A, and after draining off, dried. The dry mould is then poured over with the silver solution (B) and suspended free for a few minutes until the surface shows a dark lustre. It is then rinsed in water and treated in the same manner with the chloride of gold solution (C), whereby it acquires a yellowish tone, when, after drying, it is sufficiently prepared for the reception of the deposit. Care must be taken in preparing solution A, as the bisulphide of carbon containing phosphorus readily takes fire.

Another method is as follows: Dissolve 5 parts, by weight, of wax in 5 of warm oil of turpentine, and add to the solution a mixture of 5 parts, by weight, of phosphorus, 1 of gutta-percha, 5 of asphalt in 120 of bisulphide of carbon. When both are thoroughly mixed, add to the whole a solution of 4 parts, by weight, of gun-cotton in 60 of alcohol, and 60 of ether, and after thorough shaking allow to settle. The next day pour off the clear solution from the sediment, when the solution can at once be used. It is especially well adapted for coppering parts of plants, leaves, flowers, etc.

Another method of metallization is as follows: Immerse the leaves, etc., in iodized collodion composed of 40 per cent. alcohol 40 cubic centimetres, ether 60 cubic centimetres, potassium iodide 1 gramme, gun-cotton 1 gramme.

Allow the leaves, etc., to dry so that a firmly adhering layer is formed; then immerse them in a solution of 10 parts, by weight, of nitrate of silver in 100 of water, whereby a layer of iodide of silver is formed. Now expose the article thus treated for some time to the light, and then immerse it in the reducing fluid, con-

sisting of water 500 parts, by weight, green vitriol 25, and acetic acid of 1.04 specific gravity 25. The reduction of silver now progresses rapidly and the articles are ready for coppering. In employing this process it must not be forgotten that the layer of collodion will not stand rough usage, and hence injury to it by touching with the hands and careless placing of the conducting wire have to be avoided. By operating with the necessary care, the results are very satisfactory and sure. Instead of the iodized collodion, a mixture of equal parts of white of egg and saturated solution of common salt may be used, the remainder of the process being the same as above described.

Metallization by metallic powders.—In some cases metallization by metallic powders is to be preferred to black-leading or metallizing by the wet way. Metallic or bronze powders are metals in a state of exceedingly fine powder of which, for galvanoplastic purposes, pure copper and brass powders only are of interest. Since such metallic powders adhere badly to waxed surfaces, the mould must be provided with a well-drying coat of lacquer, upon which, before it is completely dry, the powder is scattered or sifted. When the lacquer is hard a smooth surface is produced by going over the mould with a soft brush dipped in the metallic powder, an excess being removed by a thin jet of water.

Lenoir's process—Galvanoplastic method for originals in high relief.—Lenoir's method for reproducing statues in a manner approaches in principle to that of the foundry. He begins by making with gutta-percha a mould in several pieces, which are united together so as to form a perfect hollow mould of the original. This having been done, cover all the parts carefully with black-lead. Make a skeleton with platinum wire, following the general outline of the model, but smaller than the mould, since it must be suspended in it without any point of contact. If the skeleton thus prepared is enclosed in the metallized gutta-percha mould, and the whole immersed in the galvanoplastic bath, it will be sufficient to connect the inner surface of the mould with the negative pole of the battery, and the skeleton of platinum wires (which should have no points of contact with the metallized surface of the mould) with the positive pole, in order to decompose the solution of sulphate of copper which fills the mould. When

the metallic deposit has reached the proper thickness, the gutta-percha mould is removed by any convenient process, and a faithful copy of the original will be reproduced. Lead wires may be substituted for the expensive platinum wires. This method requirės a knowledge of the moulder's art, so that good results can only be obtained by an experienced hand.

Gelatine moulds.—Under certain conditions the elasticity of gelatine allows of the possibility of its removal from undercut or highly-wrought portions of the model, when it reassumes the shape and position it had before removal therefrom. But gelatine requires that the deposit shall be made rapidly, otherwise it will swell and be partially dissolved by too long an immersion in the copper bath.

To make a good gelatine mould proceed as follows: Allow white gelatine (cabinet-maker's glue) to swell for about 24 hours in cold water, then drain off the water, and heat the swollen mass in a water bath until completely dissolved. Compound the glue solution with pure glycerine in the proportion of 5 to 10 cubic centimetres (0.24 to 0.3 cubic inch) of glycerine to 30 grammes (1.05 ozs.) of gelatine, which prevents the gelatine from shrinking in cooling. When somewhat cooled off, apply the gelatine to the oiled original, which must be surrounded with a rim of plaster of Paris or wax, to prevent the gelatine from running off; when cold lift the gelatine mould from the model. Before metallizing and suspending in the copper bath, the mould has to be prepared to resist the action of the latter, as otherwise it would at once swell and be partially dissolved before being covered with the deposit. This is effected by placing the mould in a highly concentrated solution of tannin, which possesses the property of making gelatine insoluble.

Brandley gives the following directions for preparing gelatine solution with an addition of tannin, which renders the moulds impervious to water: Dissolve 20 parts of the best gelatine in 100 of hot water, add $\frac{1}{2}$ part of tannic acid and the same quantity of rock candy, then mix the whole thoroughly, and pour it upon the model.

The same end is reached by making a mould with gelatine alone, then pouring an aqueous solution of 10 per cent. of bichro-

mate of potassium upon it, and, after draining, exposing the mould to the action of the sun.

Another method is as follows: Beat into a quart of distilled water the whites of two eggs, filter and cover with this liquid the entire surface of the gelatine mould. After drying, operate with the solution of bichromate of potassium as in the preceding. The solar action renders the coating impregnated with bichromate insoluble.

The mould must finally be metallized and, when in the bath, submitted to a strong current at the beginning. When the entire surface is covered with the copper deposit, and when swelling is no longer to be feared, a weaker current may be used.

In the following a few *special uses of galvanoplasty* will be briefly described:—

Nature printing, so named by Mr. v. Auer, Director of the Imperial Printing Office at Vienna, has for its object the galvanoplastic reproduction of leaves and other similar bodies. The leaf is placed between two plates, one of polished steel, the other of soft lead, and is then passed between rollers, which exert a considerable pressure. The leaf thus imparts an exact impression of itself and of all its veins and markings to the lead, and this impression may be electrotyped, and the copper plate produced used for printing in the ordinary way. Instead of taking the impression in lead, it is advisable to use gutta-percha or wax for delicate objects, which should previously be black-leaded or oiled. In the same manner galvanoplastic copies of laces, etc., may be obtained.

The process used by Philipp for *coating laces and tissues* with copper and then silvering or gilding, belongs rather to electroplating than to galvanoplasty. The tissue is saturated with melted wax, and after removing the excess with blotting paper it is made conductive by black-leading with a brush. It is however preferable to metallize such delicate objects by the wet way, Parke's method (p. 338) being especially suitable for the purpose, and also a treatment with weak solution of nitrate of silver and pyrogallic acid frequently alternated.

Corvin's niello.—Corvin has invented a process of producing inlaid work by galvanoplasty, which has been patented, and is

now the exclusive property of J. P. Kayser & Son, of Crefeld. The process is as follows: A matrice of metal whose surface is finely polished is first made. This matrice may be used for the production of numerous duplicates of the same kind of object. The incrustations (mother-of-pearl, glass, ivory, amber, etc.) are then shaped by means of a saw, files, and other tools to the form corresponding to that which they are to occupy in the design. The side of the incrustation which is laid upon the matrice is, as a rule, smooth. The shaped incrustations, smooth side down, are pasted on to the parts of the model they are to occupy in the design. The latter being thus produced, the backs of the non-metallic laminæ are metallized, and the portions of the metallic plate left free are slightly oiled. By now placing the matrice thus prepared in the galvanoplastic bath, the copper is deposited not only upon the metallic matrice, but also upon the back of the inlaid pieces, the latter being firmly inclosed by the deposited metal. When the deposited metal has acquired the desired thickness it is detached from the matrice, and incrustations with the right side polished are thus obtained. The laminæ are more accurately and evenly laid in than would be possible by the most skilled hand-work.

Grasses, leaves, flowers, etc., may be coated with copper and then silvered, gilded, or platinized, by first drying them, and, after giving them a certain elasticity by placing in glycerine, metallizing them by Parkes's or some other method.

Plates for the production of imitations of leather are now frequently prepared. The demand for alligator and similar leathers is at the present time greater than the supply, and, therefore, imitations are made by pressing ox-leather, the plate being prepared by galvanoplasty, as follows: A large piece of the natural skin or leather is made impervious to the bath by repeated coatings with lacquer, and, when completely dry, secured with asphalt lacquer to a copper or brass plate. The leather is then black-leaded and, after being made conductive by copper wire or small lead plates, brought into the copper bath. When the copper deposit has acquired the desired thickness, the plate is further strengthened by backing with stereotype metal.

To coat wood, etc., with a galvanoplastic deposit of copper.—The absolutely dry objects are first immersed in melted wax, paraffine, or ceresine, and when thoroughly impregnated taken out and, after draining off, allowed to cool. As the impregnating material contracts in cooling, the surface of the object is thereby freed from an excess of it. For this reason the material used for impregnating should not be made hotter than absolutely necessary, because the hotter it is the stronger the contraction or shrinkage. However, as by this contraction the edges and portions of the surface may become denuded of impregnating material, and thus be liable to be attacked by the acid copper bath, it is advisable to coat the objects, after cooling, with an acid-resisting gutta-percha lacquer prepared by dissolving 5 to 10 parts, by weight, of gutta-percha cuttings in a mixture of 50 parts each of benzine and chloroform. Keep the solution in a wide-mouthed glass bottle provided with a well-fitting cork, and apply it with a brush. The solution being very inflammable it should not be used near an open flame.

Wooden handles of surgical instruments, etc., may be protected from the attacks of the acid copper bath by coating them with a solution of wax or paraffine in ether, the latter after evaporating leaving a thin layer of wax upon the object.

The articles thus prepared are black-leaded or metallized by Parkes's or one of the methods previously given, and brought into the copper bath.

The mercury vessels of thermometers for vacuum and distilling apparatus are surrounded by a thick copper deposit to protect them from injury by mechanical force. The metallization of *glass, porcelain, clay, terra-cotta, etc.*, is effected in the same manner as above described.

Galvanoplastic operations in iron.—Under "Deposition of iron," page 293, the galvanoplastic production of heavy deposits of iron has already been referred to, it being there, also, mentioned that according to the researches of various authors a neutral solution of $1\frac{3}{4}$ ozs. of ammonio-ferrous sulphate in 1 quart of water is best adapted for the purpose, whilst Klein recommends a solution of equal parts of ferrous sulphate and sulphate of magnesia. To obtain an any way successfully iron electrotype from an original,

for instance, from a copper plate, which should previously be oiled and then coated by means of sulphuretted hydrogen with a thin layer of sulphide of silver, the following conditions have to be fulfilled: The bath must be kept absolutely neutral according to one of the methods given on page 294, under formulæ III. and IV. Further, the current-strength must be so regulated that absolutely no evolution of gas on the object is perceptible, and the distance of the anodes from the objects, which in the beginning of the operation may be $1\frac{3}{4}$ inches, must, according to Stammer, be gradually decreased to 0.19 inch. Furthermore, in the beginning of the operation the plates must at least every half hour be taken from the bath and rinsed off with a strong jet of water to remove adhering bubbles, the same object being attained by others by brushing the plates over with a feather. While out of the bath the plates must not be allowed to dry, as the fresh layers would not adhere to the places which have become dry. Now, even by strictly fulfilling the above-mentioned conditions, a faultless electrotype will be obtained only in one case out of five, this fact being mentioned in order to prevent practical electroplaters from wasting time and labor upon this process, which has not yet been sufficiently investigated and worked out. However, the interesting conditions for the production of heavy iron deposits present a field of research and observation to those who need not follow galvanoplasty for a living. In making such researches it should be especially observed whether useful heavy deposits can be obtained from *iron baths in motion.*

Galvanoplastic operations in nickel.—Though by the electro-deposition of nickel, electrotypes are rendered fit for printing with metallic colors, which attack copper, and their power of resisting wear is increased, the latter advantage can to the fullest extent be obtained only by a thick deposit. However, this always alters the design somewhat, especially the fine hatchings, this being the reason why in electro-nickelling electrotypes a deposit of medium thickness is, as a rule, not exceeded. If a hard nickel surface is desired, without injury to the fine lines of the design, the layer of nickel has to be reproduced by galvanoplasty, and the deposit of nickel strengthened in the copper bath.

But upon black-leaded gutta-percha or wax moulds a nickel

deposit can only be obtained in fresh baths; the deposit, however, is faultless only in rare cases, it generally showing holes in the depressions. Hence the object has to be attained in a roundabout way, the mode of procedure being as follows: An impression of the original is taken in gutta-percha or wax and from this impression a positive cliché in copper is made. The latter is then silvered, the silvering iodized as previously described, and a negative in copper is then prepared from this positive. The negative is again silvered, iodized, and then brought into a nickel bath where it receives a deposit of the thickness of stout writing-paper; it is then rinsed in water, and the deposit immediately strengthened in the acid copper bath; for the rest it is treated like ordinary copper deposits. Nickel electrotypes thus made are almost indestructible.

Galvanoplastic operations in silver and gold.—The preparation of reproductions in silver and gold also presents many difficulties. While copper is separable in a compact state from its sulphate solution, silver and gold have to be reduced from their double salt solutions—potassium silver cyanide and potassium auric cyanide. However, these alkaline solutions attack moulds of fatty substances, such as wax and stearine, consequently also plaster-of-Paris moulds impregnated with these substances, as well as gutta-percha and gelatine. Hence, only metallic moulds can be advantageously used except the end is to be attained in a roundabout way; that is, by first coating the mould with a thin film of copper, strengthening this in the silver or gold bath and finally dissolving the film of copper with very dilute nitric acid.

The double salt solutions mentioned above require a well-conducting surface such as cannot be readily prepared by black-leading, a further reason why metallic moulds are to be preferred. The simplest way for the galvanoplastic reproduction in gold or silver of surfaces not in high relief or undercut, is to cover the object with lead, silver, or gold foil, and pressing softened gutta-percha upon it; the foil yields to the pressure without tearing and adheres to the gutta-percha so firmly that it can be readily separated together with it. Galvanoplastic reproductions in the noble metals are so seldom made in practice that it is not neces-

sary to give further details. The composition of the baths generally used is as follows:—

Bath for galvanoplastic operations with silver.—Fine silver (in the form of silver cyanide or chloride of silver) $1\frac{3}{4}$ ozs., 98 per cent. potassium cyanide $5\frac{1}{4}$ ozs., water 1 quart.

Bath for galvanoplastic operations with gold.—Fine gold (in the form of neutral chloride of gold) 1 oz., potassium cyanide $3\frac{1}{2}$ ozs., water 1 quart.

CHAPTER XV.

COLORING, PATINIZING, OXIDIZING, ETC., OF METALS.—LACQUERING.

THOUGH, strictly speaking, these operations do not form a part of a work on the electro-deposition of metals, they require to be mentioned, since the operator is frequently forced to make use of one or the other method in order to furnish basis-metals or electro-deposits in certain shades of colors ordered.

By *patina* is understood the beautiful green color antique statues and other art-works of bronze acquire by long exposure to the action of the oxygen, carbonic acid, and moisture of the air, whereby a thin layer of copper carbonate is formed upon them. It has been sought to accelerate by chemical means the formation of the patina thus slowly produced by the influence of time, and the term *patinizing* has been applied to this artificial production of colors. Without drawing a strict line as to which processes have to be considered as coloring, and which as patinizing, the most approved methods for changing the color of the metals or of the deposits will be given.

1. *Coloring of copper.*—All shades from the pale-red of copper to a dark chestnut-brown can be obtained by superficial oxidation of the copper. For small objects it suffices to heat them uniformly over an alcohol flame; with larger objects a more uniform result is obtained by heating them in oxidizing fluids or brushing them over with an oxidizing paste, the best results being obtained with a paste prepared, according to the darker or lighter shade desired,

from 2 parts of ferric oxide and 1 part of black-lead, or 1 part each of ferric oxide and black-lead, with alcohol or water. Apply the paste as uniformly as possible with a brush and place the object in a warm place (oven or drying chamber). The darker the color is to be the higher the temperature must be, and the longer it must act upon the object. When sufficiently heated the dry powder is removed by brushing with a soft brush, and the manipulation repeated if the object does not show a sufficiently dark tone. Finally the object is rubbed with a soft linen rag moistened with alcohol, or brushed with a soft brush and a few drops of alcohol until completely dry, and then with a brush previously rubbed upon pure wax. The more or less dark shade produced in this manner is very warm and resists the action of the air.

Brown color upon copper is obtained by applying to the thoroughly cleansed surface of the object a paste of verdigris 3 parts, ferric oxide 3, sal ammoniac 1, and sufficient vinegar, and heating until the applied mixture turns black; the object is then washed and dried. By the addition of some blue vitriol the color may be darkened to chestnut-brown.

A *brown color* is also obtained by brushing to dryness with a hot solution of 1 part of potassium nitrate, 1 of common salt, 2 of ammonium chloride, and 1 of liquid ammonia in 95 of vinegar. A warmer tone is, however, produced by the method introduced in the Paris Mint, which is as follows: Powder and mix intimately equal parts of verdigris and sal ammoniac. Take a heaping tablespoonful of this mixture and boil it with water in a copper kettle for about twenty minutes and then pour off the clear fluid. To give copper objects a bronze-like color with this fluid pour part of it into a copper pan; place the objects separately in it upon pieces of wood or glass, so that they do not touch each other, or come in contact with the copper pan, and then boil them in the liquid for a quarter of an hour. Then take the objects from the solution, rub them dry with a linen cloth, and brush them with a waxed brush.

A *red-brown color* on copper is produced in China by the application of a paste of verdigris 2 parts, cinnabar 2, sal ammoniac 5,

and alum 5, with sufficient vinegar, heating over a coal fire, washing and repeating the process.

Copper is colored blue-black by dipping the object in a hot solution of $11\frac{1}{4}$ drachms of liver of sulphur in 1 quart of water, moving it constantly. *Blue-gray* shades are obtained with more dilute solutions. It is difficult to give definite directions as to the length of time the solution should be allowed to act, since this depends on its temperature and concentration. With some experience the correct treatment, however, will soon be learned.

The so-called *cuivre fumé* is produced by coloring the copper or coppered objects blue-black with solution of liver of sulphur, then rinsing, and finally scratch-brushing them, whereby the shade becomes somewhat lighter. From raised portions which are not to be dark, but are to show the color of copper, the coloration is removed by polishing upon a felt wheel or bob.

Black color upon copper is produced by a heated pickle of 2 parts of arsenic acid, 4 of concentrated muriatic acid, 1 of sulphuric acid of 66° Bé., and 24 of water.

Dead-black on copper.—Brush the object over with a solution of 1 part of platinum chloride in 5 of water, or dip it in the solution. A similar result is obtained by dipping the copper object in a solution of nitrate of copper or of manganese, and drying over a coal fire. These manipulations are to be repeated until the formation of a uniform dead-black.

Imitation of genuine patina.—Repeatedly brush the objects with solution of sal ammoniac in vinegar; the action of the solution being accelerated by the addition of verdigris. A solution of 9 drachms of sal ammoniac and $2\frac{1}{4}$ drachms of potassium binoxalate in 1 quart of vinegar acts still better. When the first coating is dry, wash the object, and repeat the manipulations, drying and washing after each application, until a *green* patina is formed. It is best to bring the articles after being brushed over with the solution into a hermetically closed box upon the bottom of which a few shallow dishes containing very dilute sulphuric or acetic acid and a few pieces of marble are placed. Carbonic acid being thereby evolved and the air in the box being kept sufficiently moist by the evaporation of water, the conditions required for the formation of genuine patina are thus fulfilled. If the patina is

to show a more *bluish* tone, brush the object with a solution of $4\frac{1}{4}$ ozs. of ammonium carbonate and $1\frac{1}{2}$ ozs. of sal ammoniac in 1 quart of water, to which a small quantity of gum tragacanth may be added.

To produce a *steel-gray color upon copper* immerse the clean and pickled objects in a heated solution of chloride of antimony in hydrochloric acid. By using a strong electric current the objects may also be coated with a steel-gray deposit of arsenic in a heated arsenic bath.

For coloring copper *dark steel-gray*, a pickle consisting of 1 quart of hydrochloric acid, 0.125 quart of nitric acid, $1\frac{1}{2}$ ozs. of arsenious acid, and a like quantity of iron filings is recommended.

Various colors upon massive copper.—First draw the object through a pickle composed of sulphuric acid 60 parts, hydrochloric acid 24.5, and lampblack 15.5; *or* of nitric acid 100 parts, hydrochloric acid $1\frac{1}{2}$, and lampblack $\frac{1}{4}$. Then dissolve in a quart of water $4\frac{1}{2}$ ozs. of sodium hyposulphite, and in another quart of water $14\frac{1}{4}$ drachms of blue vitriol, $5\frac{1}{2}$ drachms of crystallized verdigris, and $7\frac{3}{4}$ grains of sodium arsenate. Mix equal volumes of the two solutions, but no more than is actually necessary for the work in hand, and heat to between 167° and 176° F. By dipping articles of copper, brass, or nickel in the hot solution they become immediately colored with the colors mentioned below, one color passing within a few seconds into the other, and for this reason the effect must be constantly controlled by frequently taking the objects from the bath. The colors successively formed are as follows:—

Upon copper:	*Upon brass:*	*Upon nickel:*
Orange,	Golden-yellow,	Yellow,
Terra-cotta,	Lemon color,	Blue,
Red (pale),	Orange,	Iridescent.
Blood-red,	Terra-cotta,	
Iridescent.	Olive-green.	

Some of these colors not being very durable, have to be protected by a coat of lacquer or paraffine. It is further necessary to diligently move the objects, so that all portions acquire the

same color. The bath decomposes rapidly, and hence only sufficient for 2 or 3 hours' use should be mixed at one time.

2. *Coloring of brass and bronzes.*—Most of the directions given for coloring copper are also available for brass and bronzes, especially those for the production of the *green patina,* and the oxidized tones by a mixture of ferric oxide and black-lead.

Many colorations on brass, however, are effected only with difficulty, and are partially entirely unsuccessful, as, for instance, coloring black with liver of sulphur. As a pickle for the production of a:—

Lustrous black on brass, the following solution may be used: Dissolve freshly precipitated carbonate of copper, while still moist, in strong liquid ammonia, using sufficient of the copper salt so that a small excess remains undissolved, or, in other words, that the ammonia is saturated with copper. The carbonate of copper is prepared by mixing hot solutions of equal parts of blue vitriol and of soda, filtering off, and washing the precipitate.

Dilute the solution of the copper salt in ammonia with one-fourth its volume of water, add 31 to 46 grains of black-lead, and heat to between 95° and 104° F. Place the clean and pickled objects in this pickle for a few minutes, until they show a full black shade, then rinse in water, dip in hot water and dry in sawdust. The solution soon spoils, and hence no more than required for immediate use should be prepared.

Another method of coloring brass black has been given under "Deposition of Arsenic," p. 298.

Urquhart states that clean brass and copper may be covered with a firmly adherent black coating by placing them very near to the flames of burning straw. It will not rub off, and may be polished with a soft cloth.

Steel-gray on brass is obtained by the use of a mixture of 1 lb. of strong hydrochloric acid with 1 pint of water, to which are added $5\frac{1}{4}$ ozs. of iron filings and a like quantity of pulverized antimonic sulphide.

Hydrochloric acid compounded with arsenious acid is also recommended for this purpose. The mixture is brought into a lead vessel, and the objects dipped in it should come in contact with the lead of the vessel, or be wrapped around with a strip of lead.

A *gray color with a bluish tint* upon brass is produced with solution of antimonious chloride (butter of antimony), while a pure *steel-gray* color is obtained with a hot solution of arsenious chloride with a little water.

Straw color, to brown, through golden yellow, and tombac color on brass may be obtained with solution of carbonate of copper in caustic soda lye. Dissolve 5.25 ozs. of caustic soda in 1 quart of water, and add $1\frac{3}{4}$ ozs. of carbonate of copper. By using the solution cold, a *dark golden-yellow* is first formed, which finally passes through *pale brown* into *dark brown* with a green lustre; with the hot solution the coloration is more rapidly effected.

A *color resembling gold or brass* is, according to Dr. Kayser, obtained as follows: Dissolve $8\frac{1}{2}$ drachms of sodium hyposulphite in 17 drachms of water, and add 5.64 drachms of solution of antimonious chloride. Heat the mixture to boiling for some time, then filter off the red precipitate formed, and after washing it several times upon the filter with vinegar, suspend it in 2 or 3 quarts of hot water; then heat and add concentrated soda lye until solution is complete. In this hot solution dip the clean and pickled brass objects, removing them frequently to see whether they have acquired the desired coloration. The articles become *gray* by remaining too long in the bath.

Brown color, called bronze Barbédienne, on brass.—This beautiful color may be produced as follows: Dissolve by vigorous shaking in a bottle, freshly prepared arsenious sulphide in spirit of sal ammoniac, and compound the solution with antimonious sulphide until a slight permanent turbidity shows itself, and the fluid has acquired a deep yellow color. Heat the solution to 95° F., and suspend the brass objects in it. They become at first golden-yellow and then brown, but as they come from the bath with a dark dirty tone, they have to be several times scratch-brushed to bring out the color. If, after using it several times, the solution fails to work satisfactorily, add some antimonious sulphide. The solution decomposes rapidly, and should be prepared fresh every time it is to be used.

By this method only massive brass objects can be colored brown; to *brassed zinc* and *iron* the solution imparts brown-black tones, which, however, are also quite beautiful.

Upon massive brass, as well as upon brassed zinc and iron objects, bronze Barbédienne may be produced as follows: Mix 3 parts of red sulphide of antimony (*stibium sulfuratum aurantianum*) with 1 part of finely pulverized bloodstone, and triturate the mixture with ammonium sulphide to a not too thickly-fluid pigment. Apply this pigment to the objects with a brush, and, after allowing it to dry in a drying chamber, remove the powder by brushing with a soft brush.

In Paris *bronze articles* are colored *dead-yellow* or *clay-yellow* to *dark-brown* by first brushing the pickled and thoroughly rinsed objects with dilute antimony bisulphide, and, after drying, removing the coating of separated sulphur by brushing. Dilute solution of sulphide of arsenic in ammonia is then applied, the result being a color resembling mosaic gold. The more frequently the arsenic solution is applied, the browner the color becomes. By substituting for the arsenic solution one of sulphide of antimony in ammonia or ammonium sulphide, colorations of a more reddish tone are obtained.

Violet- and corn-flower blue upon brass may be produced as follows: Dissolve in 1 quart of water $4\frac{1}{2}$ ozs. of sodium hyposulphite, and in another quart of water 1 oz. $3\frac{3}{4}$ drachms of crystallized sugar of lead, and mix the solutions. Heat the mixture to 176° F., and then immerse the articles, moving them constantly. First a gold-yellow coloration appears, which, however, soon passes into violet and blue, and if the bath be allowed to act further, into green. The action is based upon the fact that in an excess of hyposulphite of soda solution of hyposulphite of lead is formed, which decomposes slowly and separates sulphide of lead, which precipitates upon the brass objects and produces the various lustrous colors.

Similar lustrous colors are obtained by dissolving 2.11 ozs. of pulverized tartar in 1 quart of water, and 1 oz. of chloride of tin in $\frac{1}{2}$ pint of water, mixing the solutions, heating, and pouring the clear mixture into a solution of 6.34 ozs. of sodium hyposulphite in 1 pint of water. Heat this mixture to 176° F., and immerse the pickled brass objects.

Ebermayer's experiments in coloring brass.—In the following the results of Ebermayer's experiments are given. In testing the

directions, the same results as those claimed by Ebermayer were not always obtained; and variations are given in parentheses.

I. Blue vitriol 8 parts by weight, crystallized sal ammoniac 2, water 100, give by boiling a *greenish* color. (The color is *olive-green*, and useful for many purposes. The coloration however succeeds only upon massive brass, but not upon brassed zinc.)

II. Potassium chlorate 10 parts by weight, blue vitriol 10, water 1000, give by boiling a *brown-orange* to *cinnamon-brown* color. (Only a *yellow-orange* color could be obtained.)

III. By dissolving 8 parts by weight of blue vitriol in 1000 of water, and adding 100 of caustic soda until a precipitate is formed, and boiling the objects in the solution, a *gray-brown* color is obtained, which can be made darker by the addition of colcothar. (Stains are readily formed. Brassed zinc acquires a pleasant *pale-brown*.)

IV. With 50 parts by weight of caustic soda, 50 of sulphide of antimony, and 500 of water, a pale *fig-brown* color is produced. (Fig-brown could not be obtained, the shade being rather *dark olive-green*.)

V. By boiling 400 parts by weight of water, 25 of sulphide of antimony, and 60 of calcined soda, and filtering the hot solution *mineral kermes* is precipitated. By taking of this 5 parts by weight and heating with 5 of tartar, 400 of water, and 10 of sodium hyposulphite, a beautiful *steel-gray* is obtained. (The result is tolerably sure and good.)

VI. Water 400 parts by weight, potassium chlorate 20, nickel sulphide 10, give after boiling for some time a *brown* color, which, however, is not formed if the sheet has been pickled. (The brown color obtained is not very pronounced.)

VII. Water 250 parts by weight, potassium chlorate 5, carbonate of nickel 2, and sulphate of ammonium and nickel 5, give after boiling for some time a *brown-yellow color*, playing into a magnificent red. (The results obtained were only indifferent.)

VIII. Water 250 parts by weight, potassium chlorate 5, and sulphate of nickel and ammonium 10, give a beautiful *dark brown*. (Upon massive brass a good dark-brown is obtained. The formula, however, is not available for brassed zinc.)

3. *Coloring zinc.*—The results obtained by coloring zinc directly according to existing directions cannot be relied on, and it is, therefore, recommended to first copper the zinc and then color the coppering. Experiments in coloring zinc *black* with alcoholic solution of chloride of antimony according to Dullas's process gave no useful results. Puscher's method is better; according to it the objects are dipped in a boiling solution of 5.64 ozs. of pure green vitriol and 3.17 ozs. of sal ammoniac in 2½ quarts of water. The loose black precipitate deposited upon the objects is removed by brushing, the object again dipped in the hot solution and then held over a coal fire until the sal ammoniac evaporates. By repeating the operation three or four times a firmly adhering black coating is formed. To color zinc black with nitrate of manganese, as proposed by Neumann, is a tedious operation, it requiring to be repeated seven or eight times. It is done by dipping the object in a solution of nitrate of manganese and heating over a coal fire, the manipulations being repeated until a uniform dead-black is obtained.

By suspending zinc in a nickel bath slightly acidulated with sulphuric acid, a firmly adhering *blue-black* coating is, after some time, formed without the use of a current. This coating is useful for many purposes. A similar result is attained by immersing the zinc objects in a solution of 2.11 ozs. of the double sulphate of nickel and ammonium and a like quantity of sal ammoniac in 1 quart of water. The articles become first *dark yellow*, then, successively, *brown*, *purple-violet*, and *indigo-blue*, and stand slight scratch-brushing and polishing.

A *gray coating on zinc* is obtained by a deposit of arsenic in a heated bath composed of 2.82 ozs. of arsenious acid, 8.46 drachms of sodium pyrophosphate, and 1¾ drachms of 98 per cent. potassium cyanide and 1 quart of water. A strong current should be used so that a vigorous evolution of hydrogen is perceptible. Platinum sheets or carbon plates are used as anodes.

A sort of *bronzing* on zinc is obtained by rubbing it with a paste of pipe-clay to which has been added a solution of 1 part by weight of crystallized verdigris, 1 of tartar, and 2 of crystallized soda.

Red-brown color on zinc.—Rub with solution of chloride of copper in liquid ammonia.

Yellow-brown shades on zinc.—Rub with solution of chloride of copper in vinegar.

4. *Coloring of iron.*—The browning of gun-barrels is effected by the application of a mixture of equal parts of butter of antimony and olive oil. Allow the mixture to act for 12 to 14 hours, then remove the excess with a woollen rag and repeat the application. When the second application has acted for 12 to 24 hours, the iron or steel will be coated with a bronze-colored layer of ferric oxide with antimony, which resists the action of the air and may be made lustrous by brushing with a waxed brush.

A lustrous black on iron is obtained by the application of solution of sulphur in spirits of turpentine prepared by boiling upon the water bath. After the evaporation of the spirits of turpentine a thin layer of sulphur remains upon the iron, which, on heating the object, immediately combines with the metal.

By another method the cleansed and picked iron objects are coated, when dry, with linseed oil, and heated to a dark red. If pickling is omitted, the coating with linseed oil and heating may have to be repeated two or three times.

According to Méritens, a lustrous black on iron is obtained by placing the articles as anode in distilled water heated to 158° F., and using an iron plate as cathode. A layer of ferroso-ferric oxide is formed, which, however, can be obtained in a firmly adhering state only upon wrought-iron. The lustre appears by brushing with a soft waxed brush. The current conducted into the bath must be just strong enough to decompose the water without perceptible evolution of gas.

According to Böttger a durable *blue* on iron and steel may be obtained by dipping the article in a ½ per cent. solution of red prussiate of potash mixed with an equal volume of a ½ per cent. ferric chloride solution.

A brown-black coating with bronze lustre on iron is obtained by heating the bright iron objects and brushing them over with concentrated solution of potassium bichromate. When dry, heat them over a charcoal fire and wash until the water running off shows no longer a yellow color. Repeat the operation twice or

three times. A similar coating is obtained by heating the iron objects with a solution of 10 parts by weight of green vitriol and 1 part of sal ammoniac in water.

To give iron a silvery appearance with high lustre.—Scour the polished and pickled iron objects with a solution prepared as follows: Heat moderately $1\frac{1}{2}$ ozs. of chloride of antimony, 0.35 oz. of pulverized arsenious acid, 2.82 ozs. of elutriated bloodstone with 1 quart of 90 per cent. alcohol upon a water bath for half an hour. Partial solution takes place. Dip into this fluid a tuft of cotton and go over the iron portions, using slight pressure. A thin film of arsenic and antimony is thereby deposited, which is the more lustrous the more carefully the iron has been previously polished.

5. *Coloring of tin.*—A *bronze-like patina* on tin may be obtained by brushing the object over with a solution of $1\frac{3}{4}$ ozs. of blue vitriol and a like quantity of green vitriol in 1 quart of water, and moistening the object when dry with a solution of $3\frac{1}{2}$ ozs. of verdigris in $10\frac{1}{2}$ ozs. of vinegar. When dry, polish the object with a soft waxed brush and some ferric oxide. The coating thus obtained being not especially durable, must be protected by a coating of lacquer.

Durable and very warm sepia-brown tone upon tin and its alloys.—Brush the object over with a solution of 1 part of platinum chloride in 10 of water, allow the coating to dry, then rinse in water, and, after again drying, brush with a soft brush until the desired brown lustre appears.

A *dark* coloration is also obtained with ferric chloride solution.

6. *Coloring of silver.*—See "Silvering," p. 242.

Lacquering.

In the electro-plating industry recourse is frequently had to lacquering in order to make the deposits more resistant against atmospheric influences, or to protect artificially prepared colors, patinas, etc. Thin, colorless shellac solution, which does not affect the color of the deposit or of the patinizing, is, as a rule, employed, while in some cases colored lacquers are used to heighten the tone of the deposit, as, for instance, gold lacquer for brass.

The lacquer is applied by means of a fine flat fitch-brush, the object having previously been heated hand-warm. After lacquering the object is dried in an oven at a temperature of between 140° and 158° F., whereby small irregularities are adjusted, and the layer of lacquer becomes transparent, clear, and lustrous.

Cellulose lacquers and varnishes.—Under the name of *zapon* a dip-lacquer has been introduced in commerce. It represents a clear, almost colorless fluid of the consistency of collodion, and smells something like fruit ether. According to G. Buchner, it consists essentially of a solution of cellulose in a mixture of amyl acetate and acetone. Of the last two bodies, the "thinning fluid," which accompanies the preparation, also consists. This lacquer can be highly recommended, its superiority being due to the favorable properties of the cellulose. The transparent, colorless coat obtained with zapon can be bent with the metallic sheet, to which it has been applied, without cracking. It is so hard that it can scarcely be scratched with the finger-nail, shows no trace of stickiness, and it is perfectly homogeneous even on the edges. This favorable behavior is very likely due to the slow evaporation of the solvent, and the fact that the lacquer quickly forms a thickish, tenacious layer, which, though moved with difficulty, is not entirely immobile. Another advantage of zapon—especially as regards metallic objects—is that the coating, in consequence of its physical constitution, preserves the character of the basis. In accordance with the nature of cellulose, the coating is not sensibly affected by ordinary differences in temperature, and does not become dull and non-transparent, as is the case with resins, in consequence of the loss of molecular coherence. It can be washed with soap and water, and protects metals coated with it from the action of the atmosphere. Zapon may also be colored, but, of course, only with coloring substances—mostly aniline colors—which are soluble in the solvent used for the cellulose.

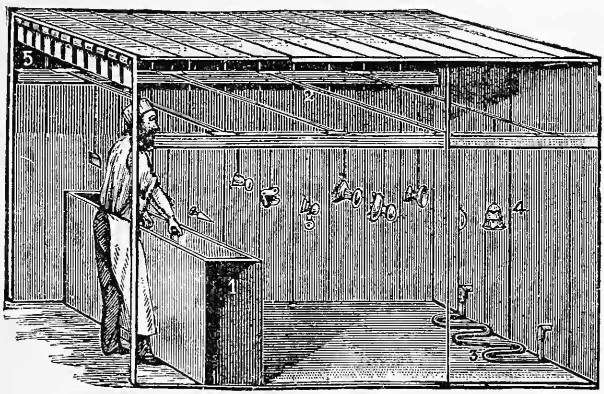
A similar preparation is known as *kristaline.* It is a hard, transparent enamel, which can be applied as a lacquer in all kinds of metal-work without affecting the most delicate finish. It is applied by dipping, is invisible, and leaves no mark in drying.

Kristaline has now been in use for about ten years, and can be relied upon to protect all metal-work from acids and alkalies, also

coal-gas, alcohol, benzine, oil, water, fly-specks, etc. It is especially designed to prevent the highest class of metal-work from tarnishing and preserve the delicate shades of color produced by electricity and artificial oxidation.

In coating articles with zapon or kristaline no special skill or apparatus is necessary; but to obtain the best results the manufacturers have adopted a form of closet or drying rack, shown in Fig. 130.

Fig. 130.



A lacquer similar to zapon or kristaline may be prepared by substituting soluble pyroxylin for cellulose, the process being as follows: Bring collodion-cotton, *i. e.*, soluble pyroxylin, such as is used by photographers, into a box which can be hermetically closed, and place upon the bottom of the box a dish with sulphuric acid. The purpose of this is to dry the collodion-cotton, which requires from 36 to 48 hours. The collodion-cotton is then brought into a large bottle, and three to four times its quantity by weight of very strong alcohol poured over it. In a few days the greater portion of it is dissolved, when the clear solution is poured into another bottle. Add to the clear solution more collodion-cotton, about 25 to 30 per cent. of the weight of the quantity originally used, and the resulting product forms an excellent cellulose lacquer, which rapidly hardens to a perfectly transparent

and very glossy coating. For diluting cellulose lacquers it is best to use wood spirit. To color them, dissolve an aniline color in strong spirits of wine, add a corresponding quantity of the solution to the lacquer, and shake vigorously.

In conclusion, a few words may be said in regard to the processes by which those magnificent effects are obtained which imitate so completely the appearance, freshness, and rich tones of real gilding. In general, gold varnish is applied only upon copper and its more or less yellow alloys.

Gold varnishers operate as follows: After the objects have been perfectly cleansed, scratch-brushed, and burnished, if necessary, they are completely dried in hot sawdust and wiped clean with a fine cloth. A light coat of varnish is then applied with a fitch-pencil, and all excess of varnish removed or levelled with another flat brush of badger-hair or bristles. The two brushes are kept together in the same hand, the varnish brush between the thumb and first two fingers, while the flat one (without a handle) is held between the other fingers and the palm of the hand. In this manner there is no interval in the use of the two brushes. The varnish is kept in a jelly-pot or other similar vessel, across the top of which a string has been stretched. This string is intended for removing by wiping the excess of varnish taken up by the brush or pencil. The varnish which covers the burnished parts of the object may be removed with a clean rag moistened with alcohol and wrapped round the finger. Another dry cloth finishes the drying. Sometimes the burnished parts are also varnished, but the operation is very difficult when their surface is considerable. Round-ware, polished or burnished, may be varnished in the lathe.

After the varnish has been applied as uniformly as possible, the objects are put in a drying stove heated to between 140° and 175° F. The alcohol or essential oils of the varnish are rapidly volatilized, while the resins or gums melt and cover the objects with a glassy lustre. The heat must be sufficient to melt these gums, but low enough to avoid burning them. When the operation has been well performed, the pieces present a beautiful and uniform golden appearance, with no disfiguring red patches, which latter indicate an unequal thickness of varnish.

Varnishers have always at their disposal four varnishes of dif-

ferent shades—*red gold, orange-yellow gold, green gold, and colorless varnish for mixture.* This last is employed for diluting the first three and diminishing the depth of their colors. Each of these various varnishes gives to copper the gold color peculiar to it, and, when mixed, intermediary shades. It often happens that the various parts of a large piece are different in composition and color, and the varnisher is obliged to impart the same shade of gold all over by skilful combinations of varnishes. He thus succeeds in giving the same gold color to half-red copper and to alloys of yellow and green brass.

But a small quantity of varnish is poured into the varnish pot at one time, to prevent it from thickening by evaporation, and after the operation the residue is poured back into the flask from which it was taken and kept well stoppered. The brushes and pencils must be often washed in alcohol, which may afterwards be used for diluting thick varnishes.

These varnishes are made by dissolving various resinous substances, like sandarac, benzoin, dragon's-blood, elemi, gamboge, etc., and tinctorial matters, such as saffron, annotto, alkanet, etc., in a mixture of alcohol with essence of lavender or of spikenard. All qualities of varnish are to be found, but the more expensive are often the more economical.

To remove the varnish from an imperfectly varnished object or from an old one it is immersed in alcohol or concentrated sulphuric acid, or, better still, in a boiling solution of caustic lye. The varnishing is then begun anew.

CHAPTER XVI.

HYGIENIC RULES FOR THE WORKSHOP.

In but few other branches of the industry has the workman so constantly to deal with powerful poisons, as well as other substances and vapors, which are exceedingly corrosive in their action upon the skin and the mucous membranes, as in electro-plating. However, with the necessary care and sobriety, all influences injurious to health may be readily overcome.

The necessity of frequently renewing the air in the workshop by thorough ventilation has already been referred to in Chapter IV., "Electro-plating establishments in general." Workmen exclusively engaged in pickling objects are advised to neutralize the action of the acid upon the enamel of the teeth and the mucous membrane of the mouth and throat by frequently rinsing the mouth with dilute solution of bicarbonate of soda. Workmen engaged in freeing the objects from grease lose, for want of cleanliness, the skin on the portions of the fingers which come constantly in contact with the lime and caustic lyes. This may be overcome by frequently washing the hands in clean water, and previous to each intermission in the work the workman should after washing the hands dip them in dilute sulphuric acid, dry them, and thoroughly rub them with cosmoline or a mixture of equal parts of glycerine and water. The use of rubber gloves by workmen engaged in freeing the objects from grease cannot be recommended, they being expensive and subject to rapid destruction. It is better to wrap a linen rag seven or eight times around a sore finger, many workmen using this precaution to protect the skin from the corrosive action of the lime.

It should be a rule for every workman employed in an electro-plating establishment not to drink from vessels used in electro-plating manipulations; for instance, porcelain dishes, beer glasses, etc. One workman may this moment use such a vessel to drink from and without his knowledge another may employ it the next moment for dipping out potassium cyanide solution, and the first using it again as a drinking vessel may incur sickness or even fatal poisoning. The handling of potassium cyanide and its solutions requires constant care and judgment. Working with sore hands in such solutions should be avoided as much as possible; but if it has to be done, and the workman feels a sharp pain in the sore, wash the latter quickly with clean water and apply a few drops of green vitriol solution. Many individuals are very sensitive to nickel solutions, eruptions, which are painful and heal slowly, breaking out upon the arms and hands, while others may for years come in contact with nickel baths without being subject to such eruptions. In such case prophylaxis is also the safeguard, *i. e.*, to prevent by immediate thorough washing the formation of

the eruption if the skin has been brought in contact with nickel solution, as, for instance, in taking out with the hand an object fallen into a nickel bath.

In the following, some directions will be found for neutralizing, in case of internal poisoning, the effects of the poison either entirely or at least sufficiently to retard its action until professional aid can be summoned.

Poisoning by hydrocyanic (prussic) acid, potassium cyanide, or cyanides.—If prussic acid, or the cyanides, be concentrated or have been absorbed in considerable quantity, their action is almost instantly fatal, and there is little hope of saving the victim, although everything possible should be tried. But if these substances have been taken in very dilute condition, they may not prove immediately fatal, and there is some hope that remedial measures may be successfully applied.

In poisoning, with these substances *water as cold as possible* should be run upon the head and spine of the patient, and he should be made to inhale, carefully and moderately, the vapor of chlorine water, bleaching powder, or Javelle water (hypochlorite of soda).

Should these poisons be introduced into the stomach, there should be administered as soon as possible the hydrate of sesquioxide of iron, or, what is better, dilute solutions of the acetate, citrate, or tartrate of iron. With proper precautions a very dilute solution of sulphate of zinc may be given.

Poisoning by copper-salts.—The stomach should be quickly emptied by means of an emetic or, in want of this, the patient should thrust his finger to the back of his throat and induce vomiting by tickling the *uvula.* After vomiting drink milk, white of egg, gum-water, or some mucilaginous decoction.

Poisoning by lead-salts requires the same treatment as poisoning by copper-salts. Lemonade of sulphuric acid, or an alkaline solution containing carbonic acid, such as Vichy water, or bicarbonate of soda, is also very serviceable.

Poisoning by arsenic.—The stomach must be quickly emptied by an energetic emetic, when freshly precipitated ferric hydrate and calcined magnesia may be given as an antidote. Calcined

magnesia being generally on hand, mix it with 15 to 20 times the quantity of water and give of this mixture 3 to 6 tablespoonfuls every 10 to 15 minutes.

Poisoning by alkalies.—Use weak acids, such as vinegar, lemon-juice, etc., and in their absence sulphuric, hydrochloric, or nitric acid diluted to the strength of lemonade. After the pain in the stomach has diminished, it will be well to administer a few spoonfuls of olive oil.

Poisoning by mercury-salts.—Mercury salts, and particularly the chloride (corrosive sublimate), form with the white of egg (albumen) a compound very insoluble and inert. The remedy is therefore indicated. Sulphur and sulphuretted water are also serviceable for the purpose.

Poisoning by sulphuretted hydrogen.—The patient should be made to inhale the vapor of chlorine from chlorine water, Javelle water, or bleaching-powder. Energetic friction, especially at the extremities of the limbs, should be employed. Large quantities of warm and emollient drinks should be given and abundance of fresh air.

Poisoning by chlorine, sulphurous acid, nitrous and hyponitric gases.—Admit immediately an *abundance of fresh air*, and administer *light* inspirations of ammonia. Give plenty of hot drinks and excite friction, in order to conserve the warmth and transpiration of the skin. Employ hot foot-baths to remove the blood from the lungs. Afterwards maintain in the mouth of the patient some substance which, melting slowly, will keep the throat moist, such as jujube and marshmallow paste, molasses candy, and liquorice paste. Milk is excellent.

CHAPTER XVII.

CHEMICAL PRODUCTS AND VARIOUS APPARATUS AND INSTRUMENTS USED IN ELECTRO-PLATING.

A. *Chemical Products.*

In the following the characteristic properties of the chemical products employed in the workshop will be briefly discussed, and the reactions indicated which allow of their recognition. It frequently happens that the labels become detached from the bottles and boxes, thus rendering the determination of their contents necessary.

I. *Acids.*

1. *Sulphuric acid* (*oil of vitriol*).—Two varieties of this acid are found in commerce, viz., fuming sulphuric acid (disulphuric acid), and ordinary sulphuric acid. The first is a thick oily fluid generally colored yellowish by organic substances, and emits dense white vapors in the air. Its specific gravity is 1.87 to 1.89. The only purpose for which fuming sulphuric acid is used in the electro-plating art is as a mixture with nitric acid, for stripping silvered objects.

Ordinary sulphuric acid has a specific gravity of 1.84. Diluted with water it serves for filling the Bunsen elements and as a pickle for iron; in a concentrated state it is used in the preparation of pickles and as an addition to the galvanoplastic copper bath. The crude commercial acid generally contains arsenic, hence care must be had to procure a pure article. In diluting the acid with water, it should in all cases be added to the water in a very gentle stream and with constant stirring, as otherwise a sudden generation of steam of explosive violence might result, and the dangerous corrosive liquid be scattered in all directions. Concentrated sulphuric acid vigorously attacks all organic substances, and hence

has to be kept in bottles with glass stoppers, and bringing it in contact with the skin should be carefully avoided.

Recognition.—One part of acid mixed with 25 parts of distilled water gives, when compounded with a few drops of barium chloride solution, a white precipitate of barium sulphate.

2. *Nitric acid* (*aqua fortis, spirit of nitre*).—It is found in trade of various degrees of strength; for our purposes acid of 40° and 30° Bé., being generally used. The acid is usually a more or less deep yellow, and frequently contains chlorine. The vapors emitted by nitric acid are poisonous and of a characteristic odor, by which the concentrated acid is readily distinguished from other acids. It is used for filling the Bunsen elements, and for pickling in combination with sulphuric acid and chlorine. On coming in contact with the skin it produces yellow stains.

Recognition.—By heating the not too dilute acid with copper, brown-red vapors are evolved. For the determination of dilute nitric acid, add a few drops of it to green vitriol solution, when a black-brown coloration will be produced on the point of contact.

3. *Hydrochloric acid* (*muriatic acid*).—The pure acid is a colorless fluid which emits abundant fumes in contact with the air, and has a pungent odor by which it is readily distinguished from other acids. The specific gravity of the strongest hydrochloric acid is 1.2; the crude acid of commerce has a yellow color, due to iron, and contains arsenic. Dilute hydrochloric acid is used for pickling iron and zinc.

Recognition—On adding to the acid strongly diluted with distilled water a few drops of solution of nitrate of silver in distilled water a heavy white precipitate is formed, which becomes black by exposure to the light.

4. *Hydrocyanic acid* (*prussic acid*).—This extremely poisonous acid exists in nature only in a state of combination in certain vegetables and fruits, and especially in the kernels of the latter, as, for instance, in the peach, the berries of the cherry laurel, bitter almonds, the stones of the apricot, of plums, cherries, etc. It may be obtained anhydrous, but in this state it is useless, and very difficult to preserve from decomposition. Diluted hydrocyanic acid is colorless, with a bitter taste and the characteristic

smell of bitter almonds. It is employed in the preparation of gold immersing baths, and for the decomposition of the potassa in old silver baths. The inhalation of the vapors of this acid may have a fatal effect, as also its coming in contact with wounds.

Recognition.—By its characteristic smell of bitter almonds. Or mix it with potash lye until blue litmus paper is no longer reddened, then add solution of green vitriol which has been partially oxidized by standing in the air, and acidulate with hydrochloric acid. A precipitate of Berlin blue is formed.

5. *Citric acid.*—Clear colorless crystals of 1.542 specific gravity, which dissolve with great ease in both hot and cold water. It is frequently employed for acidulating nickel baths and, combined with sodium citrate, in the preparation of platinum baths.

Recognition.—Lime-water compounded with aqueous solution of citric acid remains clear in the cold, but on boiling deposits a precipitate of calcium citrate. This precipitate is soluble in ammonium chloride, but on boiling is again precipitated, and is then insoluble in sal ammoniac.

6. *Boric acid* (*boracic acid*).—This acid is found in commerce in the shape of scales with nacreous lustre and greasy to the touch; when obtained from solutions by evaporation, it forms colorless prisms. Its specific gravity is 1.435; it dissolves with difficulty in cold water (1 part of acid requiring, at 64.4° F., 28 of water), but is more rapidly soluble in boiling water (1 part of acid requiring 3 of water at 212° F.). According to Weston's proposition, boric acid is employed as an addition to nickel baths, etc.

Recognition.—By mixing solution of boric acid in water with some hydrochloric acid and dipping turmeric paper in the solution, the latter acquires a brown color, the color becoming more intense on drying. Alkalies impart to turmeric paper a similar coloration, which, however, disappears on immersing the paper in dilute hydrochloric acid.

7. *Arsenious acid* (*white arsenic, arsenic, ratsbane*).—It generally occurs in the shape of a white powder and sometimes in vitreous-like lumps, resembling porcelain; for our purposes the white powder is almost exclusively used. It is slightly soluble in cold water, and more readily in hot water and hydrochloric acid. Not-

withstanding its greater specific gravity (3.7) only a portion of the powder sinks to the bottom on mixing it with water, another portion being retained on the surface by air bubbles adhering to it. It is employed as an addition to brass baths, further, in the preparation of arsenic baths, for blacking copper alloys, and in certain silver whitening baths.

Recognition.—When some arsenious acid is thrown upon glowing coals an odor resembling that of garlic is perceptible. By mixing solution of arsenious acid, prepared by boiling with water, with a few drops of ammoniacal solution of nitrate of silver, a yellow precipitate of arsenate of silver is obtained. The ammoniacal solution of nitrate of silver is prepared by adding ammonia to solution of nitrate of silver until the precipitate at first formed disappears.

8. *Chromic acid.*—It forms crimson-red needles, and also occurs in commerce in the shape of a red powder. It is readily soluble in water, forming a red fluid which serves for filling batteries.

Recognition—Chromic acid can scarcely be mistaken for any other chemical product employed by the electro-plater. A strongly diluted solution of it gives, after neutralizing with caustic alkali and adding a few drops of nitrate of silver solution, a crimson-red precipitate of chromate of silver.

II. *Alkalies and Alkaline Earths.*

9. *Potassium hydrate* (*caustic potash*).—It is found in commerce in various degrees of purity, either in sticks or cakes. It is very deliquescent and dissolves readily in water and alcohol; by absorbing carbonic acid from the air it rapidly becomes converted into the carbonate and thus loses its caustic properties. It should, therefore, be stored in well-closed vessels. Substances moistened with solution of caustic potash give rise to a peculiar soapy sensation of the skin when touched. It should never be allowed to enter the mouth, as even dilute solutions almost instantaneously remove the lining of tender skin. Should such an accident happen, the mouth should be at once several times rinsed with water and then with very dilute acetic acid. Pure caustic potash serves as an addition to zinc baths, gold baths, etc. For the purpose of

freeing objects from grease the more impure commercial article is used.

10. *Sodium hydrate* (*caustic soda*).—It also occurs in commerce in various degrees of purity, either in sticks or lumps. It is of a highly caustic character resembling potassium hydrate (see above) in properties and effects. It is employed for freeing objects from grease.

11. *Ammonium hydrate* (*ammonia or spirits of hartshorn*).—It is simply water saturated with ammonia gas. By exposure ammonia gas is gradually evolved, so that it must be stored in closely-stoppered bottles in order to preserve the strength of the solution unimpaired. Four qualities are generally found in commerce, viz., ammonia of 0.910 specific gravity (containing 24.2 per cent. of ammonia gas); of 0.920 specific gravity (with 21.2 per cent. of ammonia gas); of 0.940 specific gravity (with 15.2 per cent. of ammonia gas); and 0.960 specific gravity (with 9.75 per cent. of ammonia gas). It is employed for neutralizing nickel and cobalt baths when too acid, in the preparation of fulminating gold, and as an addition to some copper and brass baths.

Recognition.—By the odor.

12. *Calcium hydrate* (*burnt or quick lime*).—It forms hard, white to gray pieces, which on moistening with water crumble to a light white powder, evolving thereby much heat. Vienna lime is burnt lime containing magnesia. Lime serves for freeing objects from grease, and for this purpose is made into a thinly-fluid paste with chalk and water with which the objects to be freed from grease are brushed. Vienna lime is much used as a polishing agent.

III. *Sulphur Combinations.*

13. *Sulphuretted hydrogen* (*sulphydric acid, hydrosulphuric acid*).—A very poisonous colorless gas with a fetid smell resembling that of rotten eggs. Ignited in the air it burns with a blue flame, sulphurous acid and water being formed. At the ordinary temperature water absorbs about three times its own volume of the gas, and then acquires the same properties as the gas itself. Sulphuretted hydrogen serves for the metallizing of moulds as

described on p. 338, where the manner of evolving it is also given. It is sometimes employed for the production of "oxidized" silver. Bringing not only metallic salts, but gilt or silvered articles, or pure gold and silver, in contact with sulphuretted hydrogen, should be carefully avoided, they being rapidly sulphurized by it.

Recognition.—By its penetrating smell; further, by a strip of paper moistened with sugar of lead solution becoming black when brought into a solution or an atmosphere containing sulphuretted hydrogen.

14. *Potassium sulphide* (*liver of sulphur*).—It forms a hard green-yellow to pale brown mass, with conchoidal fracture; it readily absorbs moisture, whereby it deliquesces and smells of sulphuretted hydrogen. It is employed for coloring copper and silver black.

Recognition.—On pouring an acid over liver of sulphur sulphuretted hydrogen is evolved with effervescence, sulphur being at the same time separated.

15. *Ammonium sulphide* (*sulphydrate or hydrosulphate of ammonia*).—When freshly prepared it forms a clear and colorless fluid, with an odor of ammonia and sulphuretted hydrogen; by standing it becomes yellow, and, later on, precipitates sulphur. It is used for the same purpose as liver of sulphur.

16. *Carbon disulphide or bisulphide.*—Pure carbon disulphide is a colorless and transparent liquid, which is very dense, and exhibits the property of double refraction. Its smell is characteristic and most disgusting, and may be compared to that of rotten turnips. It burns with a blue flame of sulphurous acid, carbonic acid being at the same time produced. It is used as a solvent for phosphorus and caoutchouc in metallizing moulds according to Parkes's method. This solution should be very carefully handled.

17. *Antimony sulphide.*—a. *Black sulphide of antimony* (*stibium sulfuratum nigrum*) is found in commerce in heavy, gray, and lustreless pieces or as a fine black-gray powder, with slight lustre. It serves for the preparation of antimony baths, and for coloring copper alloys black.

b. *Red sulphide of antimony* (*stibium sulfuratum aurantiacum*) forms a delicate orange-red powder without taste or odor; it is insoluble in water, but soluble in ammonium sulphide, spirits of hartshorn, and alkaline lyes. In connection with ammonium sulphide or ammonia it serves for coloring brass brown.

18. *Arsenic trisulphide or arsenious sulphide* (*orpiment*).—It is found in commerce in the natural as well as artificial state, the former occurring mostly in kidney-shaped masses of a lemon color, and the latter in more orange-red masses, or as a dull yellow powder. Specific gravity 3.46. It is soluble in the alkalies and spirits of sal ammoniac.

19. *Ferric sulphide.*—Hard black masses generally in flat plates which are only used for the evolution of sulphuretted hydrogen.

IV. *Chlorine Combinations.*

20. *Sodium chloride* (*common salt, rock salt*).—The pure salt should form white cubical crystals, of which 100 parts of cold water dissolve 36, hot water dissolving slightly more. The specific gravity of sodium chloride is 2.2. In electroplating sodium chloride is employed as a conducting salt for some gold baths, as a constituent of argentiferous pastes, and for precipitating the silver as chloride from argentiferous solutions.

Recognition.—An aqueous solution of sodium chloride on being mixed with a few drops of lunar caustic solution yields a white caseous precipitate, which becomes black by exposure to light and does not disappear by the addition of nitric acid, but is dissolved by ammonia in excess.

21. *Ammonium chloride* (*sal ammoniac*).—A white substance found in commerce in the shape of tough fibrous crystals. It has a sharp saline taste, and is soluble in $2\frac{3}{4}$ parts of cold, and in a much smaller quantity of hot water. By heat it is sublimed without decomposition. It serves for soldering and tinning, and as a conducting salt for many baths.

Recognition.—By the sublimation on heating. By adding to a saturated solution of the salt a few drops of solution of platinum chloride, a yellow precipitate of platoso-ammonium chloride is formed.

22. *Antimony trichloride* (*butter of antimony*).—A crystalline mass which readily deliquesces in the air. Its solution in hydrochloric acid yields the *liquor stibii chlorati*, also called liquid butter of antimony; it has a yellowish color, and on mixing with water yields an abundant white precipitate soluble in potash lye. The solution serves for coloring brass steel-gray, and for browning gun-barrels.

23. *Arsenious chloride.*—A thick oily fluid, which evaporates in the air with the emission of white vapors.

24. *Copper chloride.*—Blue-green crystals readily soluble in water. The concentrated solution is green, and the dilute solution blue. On evaporating to dryness, brown-yellow copper chloride is formed. It is employed in copper and brass baths as well as for patinizing.

25. *Tin chloride.*—a. *Stannous chloride or tin salt.* A white crystalline salt readily soluble in water, but its solution on exposure to the air becomes turbid; by adding, however, hydrochloric acid, it again becomes clear. On fusing the crystallized salt it loses its water of crystallization, and forms a solid non-transparent mass of a pale-yellow color—the fused tin salt. The crystallized, as well as the fused, salt serves for the preparation of brass, bronze, and tin baths.

Recognition.—By pouring hydrochloric acid over a small quantity of tin salt and adding potassium chromate solution, the solution acquires a green color. By mixing dilute tin salt solution with some chlorine water and adding a few drops of gold chloride solution, purple of Cassius is precipitated; very dilute solutions acquire a purple color.

b. *Stannic chloride* occurs in commerce in colorless crystals, and in the anhydrous state forms a yellowish, strongly fuming caustic liquid known as the "fuming liquor of Libadius."

26. *Zinc chloride* (*hydrochlorate or muriate of zinc; butter of zinc*).—A white crystalline or fused mass which is very soluble and deliquescent. The salt prepared by evaporation generally contains some zinc oxychloride, and hence does not yield an entirely clear solution. It serves for preparing brass and zinc baths, and its solution for nickelling by immersion, soldering, etc.

Recognition.—Solution of caustic potash separates a voluminous precipitate of zinc oxyhydrate, which redissolves in an excess of the caustic potash solution. By conducting sulphuretted hydrogen into a solution of a zinc salt acidulated with acetic acid, a precipitate of white zinc sulphide is formed.

27. *Zinc chloride and ammonium chloride.*—This salt is a combination of zinc chloride with sal ammoniac, and forms a white very deliquescent powder. Its solution serves for soldering and for zincking by contact.

28. *Nickel chloride.*—It is found in commerce in the shape of deep green crystals and of a pale green powder; the latter contains considerably less water and less free acid than the crystallized article, and is to be preferred for electro-plating purposes. The crystallized salt dissolves readily in water, and the powder somewhat more slowly; should the solution of the latter deposit a yellow precipitate, consisting of basic nickel chloride, it has to be brought into solution by the addition of a small quantity of hydrochloric acid. Nickel chloride is employed for nickel baths.

Recognition.—By mixing the green solution of the salt with some spirits of sal ammoniac, a precipitate is formed which dissolves in an excess of spirits of sal ammoniac, the solution showing a deep blue color.

29. *Cobalt chloride.*—It forms small rose-colored crystals, which, on heating, yield their water of crystallization and are converted into a blue mass. The crystals are readily soluble in water, while the anhydrous blue powder dissolves slowly. Cobalt chloride is employed for the preparation of cobalt baths.

Recognition.—Caustic potash precipitates from a solution of cobalt chloride a blue basic salt which is gradually converted into a rose-colored hydrate, and, with the access of air, into green-brown cobaltous hydrate; the aqueous solution yields with solution of yellow prussiate of potash a pale gray-green precipitate.

30. *Silver chloride* (*horn silver*).—A heavy white powder gradually passing, by exposure to white light, through a gradation of shades from violet to black. By precipitation from silver solutions it separates as a caseous precipitate (p. 245). At 500° F. it melts, without decomposing, to a yellowish fluid, which, on cooling, congeals to a transparent, tenacious, horn-like mass. Chloride

of silver is practically insoluble in water, but dissolves readily in spirits of sal ammoniac and in potassium cyanide solution. It is employed in the preparation of baths for electro-silvering, for the whitening baths, and for the pastes for silvering by friction.

Recognition.—By its solubility in ammonia, pulverulent metallic silver being separated from the solution by dipping in it bright ribbands of copper.

31. *Gold chloride* (*terchloride of gold, muriate of gold, auric chloride*).—This salt occurs in commerce as crystallized gold chloride of an orange-yellow color, and as a brown crystalline mass, which is designated as neutral gold chloride, or as gold chloride free from acid, whilst the crystallized article always contains acid, and, hence, should not be used for gold baths. Gold chloride absorbs atmospheric moisture and becomes resolved into a liquid of a fine gold color. On being moderately heated yellowish-white aurous chloride is formed, and on being subjected to stronger heat it is decomposed to metallic gold and chlorine gas. By mixing its aqueous solution with ammonia, a yellow-brown powder consisting of *fulminating gold* is formed. In a dry state this powder is highly explosive, and, hence, when precipitating it from gold chloride solution for the preparation of gold baths, it must be used while still moist.

Recognition.—By the formation of the precipitate of fulminating gold on mixing the gold chloride solution with ammonia. Further by the precipitation of brown metallic gold powder on mixing the gold chloride solution with green vitriol solution.

32. *Platinic chloride.*—The substance usually known by this name is *hydroplatinic chloride.* It forms red-brown very soluble —and in fact deliquescent—crystals. With ammonium chloride it forms platoso-ammonium chloride (see p. 276). Both combinations are used in the preparation of platinum baths. The solution of platinic chloride also serves for coloring silver, tin, brass, and other metals.

Recognition.—By the formation of a precipitate of yellow platoso-ammonium chloride by mixing concentrated platinic chloride solution with a few drops of saturated sal ammoniac solution.

V. *Cyanides.*

33. *Potassium cyanide* (*white prussiate of potash*).—For electroplating purposes pure potassium cyanide with 98 to 99 per cent., as well as that containing 80, 70, and 60 per cent., is used, whilst for pickling the preparation with 45 per cent. is employed. For the preparation of alkaline copper and brass baths, as well as silver baths, the pure 98 to 99 per cent. product is generally employed. However, for preparing gold baths the 60 per cent. article is mostly preferred, because the potash present in all potassium cyanide varieties with a lower content renders fresh baths more conductive. However, gold baths may also be prepared with 98 per cent. potassium cyanide without fear of injury to the efficiency of the baths, while, under ordinary circumstances, a preparation with less than 98 per cent. may safely be used for the rest of the baths. However, when potassium cyanide has to be added to the baths, as is from time to time necessary, only the pure preparation free from potash should be used, because the potash contained in the inferior qualities gradually thickens the bath too much.

No product is more important to the electro-plater than potassium cyanide. The pure 98 to 99 per cent. product is a white transparent crystalline mass, the crystalline structure being plainly perceptible upon the fracture. In a dry state it is odorless, but when it has absorbed some moisture it has a strong smell of prussic acid. It is readily soluble in water, and should be dissolved in *cold* water only, since when poured into hot water it is partially decomposed, which is recognized by the appearance of an odor of ammonia. Potassium cyanide solution in cold water may, however, be boiled for a short time without suffering essential decomposition. Potassium cyanide must be kept in well-closed vessels, being when exposed to the air deliquescent, and it is decomposed by the carbonic acid of the air, whereby potassium carbonate is formed while prussic acid escapes. It is a deadly poison and must be used with the utmost caution. Potassium cyanide with 80, 70, 60, or 45 per cent. forms a gray-white to white mass with a porcelain-like fracture. A pale gray coloration is not a proof of impurities, it being due to somewhat too high a tem-

perature in fusing. These varieties are found in commerce in irregular lumps or in sticks, the use of the latter offering no advantage. Their behavior towards the air and in dissolving is the same as that of the pure product.

Recognition.—By the bitter almond smell of the solution. By mixing potassium cyanide solution with ferric chloride and then with hydrochloric acid until the latter strongly predominates, a precipitate of Berlin blue is formed.

The pure salt free from potash does not effervesce on adding dilute acid, which is, however, the case with the inferior qualities.

To facilitate the use of potassium cyanide with a different content than that given in a formula for preparing a bath, the following table is here given :—

Potassium cyanide with				
98 per cent.	80 per cent.	70 per cent.	60 per cent.	45 per cent.
By weight.	By weight.	By weight.	By weight.	By weight.
1 part	= 1.230 parts	= 1.400 parts	= 1.660 parts	= 2.180 parts.
0.820 "	= 1 "	= 1.143 "	= 1.333 "	= 1.780 "
0.714 "	= 0.875 part	= 1. part	= 1.170 "	= 1.550 "
0.615 "	= 0.750 "	= 0.857 "	= 1 part	= 1.450 "
0.460 "	= 0.562 "	= 0.643 "	= 0.750 "	= 1 part

34. *Copper cyanides.*—There is a cuprous and a cupric cyanide; that used for electro-plating purposes being a mixture of both. It is a green-brown powder, which should not be dried, since in the moist state it dissolves more readily in potassium cyanide. It is only used as a double salt, *i. e.*, in combination with potassium cyanide in the preparation of copper, brass, tombac, and red gold baths.

Recognition—By evaporating a piece of copper cyanide the size of a pea, or its solution in hydrochloric acid to dryness in a water bath, whereon care must be taken not to inhale the vapors, and dissolving the residue in water, a green-blue solution is obtained which acquires a deep blue color by the addition of ammonia in excess.

35. *Zinc cyanide* (*hydrocyanate of zinc, prussiate of zinc*).—A white powder insoluble in water, but soluble in potassium cyanide,

ammonia and the alkaline sulphites; the fresher it is, the more readily it dissolves, the dried product dissolving with difficulty. Its solution in potassium cyanide is used for brass baths.

Recognition.—By evaporating zinc cyanide or its solution in an excess of hydrochloric acid, zinc chloride remains behind, which is recognized by the reaction given under zinc chloride.

36. *Silver cyanide* (*prussiate, or hydrocyanate of silver*).—A white powder which slowly becomes black when exposed to light. It is insoluble in water and cold acids, which, however, will dissolve it with the aid of heat. At 750° F. it melts to a dark red fluid, which, on cooling, forms a yellow mass with a granular structure. It is readily dissolved by potassium cyanide, but is only slightly soluble in ammonia, differing in this respect from silver chloride. It forms a double salt with potassium cyanide, and as such is employed in the preparation of silver baths.

37. *Potassium ferro-cyanide* (*yellow prussiate of potash*).—It occurs in the shape of yellow semi-translucent crystals with mother-of-pearl lustre, which break gradually and without noise. For the solution of 1 part of it, 4 of water are required, the solution exhibiting a pale yellow color. It precipitates nearly all the metallic salts from their solutions, some of the precipitates being soluble in an excess of the precipitating agent. This salt is not poisonous. It serves for the preparation of silver and gold baths; its employment, however, offering no advantages over potassium cyanide except its non-poisonous properties be considered as such.

Recognition.—When the yellow solution is mixed with ferric chloride a precipitate of Berlin blue is formed.

VI. *Carbonates.*

38. *Potassium carbonate* (*potash*).—It is found in commerce in gray-white, bluish, yellowish pieces, the colorations being due to admixtures of small quantities of various metallic oxides, and pure in the form of a white powder or in pieces the size of a pea. The salt, being very deliquescent, has to be kept in well-closed receptacles. It is readily soluble, and, if pure, the solution in

distilled water must be clear. It serves as an addition to some baths, and in an impure state for freeing objects from grease.

Recognition.—The solution effervesces on the addition of hydrochloric acid. The solution neutralized with hydrochloric acid gives with platinum chloride a heavy yellow precipitate, provided the solution be not too dilute.

39. *Acid potassium carbonate or monopotassic carbonate, commonly called bicarbonate of potash.*—Colorless transparent crystals, which at a medium temperature dissolve to a clear solution in 4 parts of water. It is not deliquescent; however, on boiling its solution loses carbonic acid, and contains then only potassium carbonate. It is employed for the preparation of certain baths for gilding by simple immersion.

40. *Sodium carbonate* (*washing soda*).—It occurs in commerce as crystallized or calcined soda of various degrees of purity. The crystallized product forms colorless crystals or masses of crystals, which, on exposure to air, rapidly effloresce and crumble to a white powder. By glowing, the crystals also lose their water, a white powder, the so-called calcined soda, remaining behind. Soda dissolves readily in water, and serves as an addition to copper and brass baths, for the preparation of metallic carbonates, and for freeing objects from grease, the ordinary impure soda being used for the latter purpose.

The directions for additions of sodium carbonate to baths generally refer to the crystallized salt. If calcined soda is to be used instead, 0.4 part of it will have to be taken for 1 part of the crystallized product.

41. *Sodium bicarbonate* (*baking powder*).—A dull white powder soluble in 10 parts of water of 68° F. On boiling, the solution loses one-half of its carbonic acid, and then contains sodium carbonate only.

42. *Calcium carbonate* (*marble, chalk*).—When pure it forms a snow-white crystalline powder, a yellowish color indicating a content of iron. It is insoluble in water, but soluble, with effervescence, in hydrochloric, nitric, and acetic acids. In nature, calcium carbonate occurs as marble, limestone, chalk.

In the form of *whiting* (ground chalk carefully freed from all stony matter) it is used for the removal of an excess of acid in

acid copper baths, and mixed with burnt lime as an agent for freeing objects from grease.

43. *Copper carbonate.*—Occurs in nature as malachite and allied minerals. The artificial carbonate is an azure-blue substance, insoluble in water, but soluble, with effervescence, in acids. Copper carbonate precipitated from copper solution by alkaline carbonates has a greenish color. Copper carbonate is employed for copper and brass baths, and for the removal of an excess of acid in acid copper baths.

Recognition.—Dissolves in acids with effervescence; on dipping a ribband of bright sheet-iron in the solution, copper separates upon the iron. On compounding the solution with ammonia in excess, a deep blue coloration is obtained.

44. *Zinc carbonate.*—A white powder, insoluble in water. The product obtained by precipitating a zinc salt with alkaline carbonates is a combination of zinc carbonate with zinc oxyhydrate. It serves for brass baths in connection with potassium cyanide.

Recognition.—In a solution in hydrochloric acid, which is formed with effervescence, according to the reactions given under zinc chloride (26).

45. *Nickel carbonate.*—A pale apple-green powder, insoluble in water, but soluble, with effervescence, in acids. It is employed for neutralizing nickel baths which have become acid.

Recognition.—In hydrochloric acid it dissolves, with effervescence, to a green fluid; by the addition of a small quantity of ammonia, nickel oxyhydrate is precipitated, which, by adding ammonia in excess, is redissolved, the solution showing a blue color.

46. *Cobalt carbonate.*—A reddish powder, insoluble in water, but soluble in acids, the solution forming a red fluid.

VII. *Sulphates and Sulphites.*

47. *Sodium sulphate* (*Glauber's salt*).—Clear crystals of a slightly bitter taste, which effloresce by exposure to the air. They are readily soluble in water. On heating, the crystals melt in their water of crystallization, and on glowing, calcined Glauber's salt remains behind. It is used as an addition to some baths.

48. *Ammonium sulphate.*—It forms a neutral colorless salt, which is constant in the air, readily dissolves in water, and evaporates on heating. It serves as a conducting salt for nickel, cobalt, and zinc baths.

Recognition.—By its evaporating on heating; a concentrated solution compounded with platinic chloride gives a yellow precipitate of platoso-ammonium chloride, while a solution mixed with a few drops of hydrochloric acid gives with barium chloride a precipitate of barium sulphate.

49. *Aluminium-potassium sulphate* (*potash-alum*).—Colorless crystals or pieces of crystals with an astringent taste. It is soluble in water, 12 parts of it dissolving in 100 parts of water at the ordinary temperature. On heating, the crystals melt, and are converted into a white spongy mass, the so-called burnt alum. Potash-alum serves for the preparation of zinc baths and for brightening the color of gold.

Recognition.—On adding sodium phosphate to the solution a jelly-like precipitate of aluminium phosphate is formed, which is soluble in caustic potash, but insoluble in acetic acid.

50. *Ammonium-alum* is exactly analogous to the above, the potassium sulphate being simply replaced by ammonium sulphate. It is for most purposes interchangeable with potash-alum. On glowing ammonium-alum the ammonium sulphate is lost, pure alumina remaining behind. Ammonium-alum is used for preparing a bath for zincking iron and steel by immersion.

Recognition.—The same as potash-alum. On heating the comminuted ammonium-alum with potash lye an odor of ammonia becomes perceptible.

51. *Iron sulphate* (*iron protosulphate, ferrous sulphate or green vitriol*).—Pure green vitriol forms bluish-green transparent crystals of a sweetish astringent taste, which readily dissolve in water. Crude green vitriol is a green crystalline substance, often yellowish on the exterior owing to the formation of ferric compounds with the aid of atmospheric oxygen. It generally contains, besides ferrous sulphate, the sulphates of copper and zinc as well as ferric sulphate. On account of the tendency to peroxidation, green vitriol and other ferrous compounds should not be exposed to the air any more than is necessary. Green vitriol is employed

for the preparation of iron baths, and for the reduction of gold from its solutions.

Recognition.—By compounding the green solution with a few drops of concentrated nitric acid, a black-blue ring is formed on the point of contact. On mixing the lukewarm solution with gold chloride, gold is separated as a brown powder, which by rubbing acquires the lustre of gold.

52. *Iron-ammonium sulphate.*—Green crystals which are constant in the air and do not oxidize as readily as green vitriol. 100 parts of water dissolve 16 parts of this salt. It is used for the same purposes as green vitriol.

53. *Copper sulphate (cupric sulphate or blue vitriol).*—It forms blue crystals, of which 100 parts of cold water dissolve about 40, and the same volume of hot water about 200 parts. Blue vitriol which does not possess a pure blue color, but shows a greenish lustre, is contaminated with green vitriol, and should not be used for electro-plating purposes. Blue vitriol serves for the preparation of alkaline copper and brass baths, acid copper baths, etc.

Recognition.—By its appearance, as it can scarcely be mistaken for anything else. A content of iron is recognized by boiling blue vitriol solution with a small quantity of nitric acid, and adding spirits of sal ammoniac in excess; brown flakes indicate iron.

54. *Zinc sulphate (white vitriol).*—It forms small colorless prisms of a harsh metallic taste, which readily oxidize on exposure to the air. By heating the crystals melt, and by glowing are decomposed into sulphurous acid and oxygen, which escape, while zinc oxide remains behind as residue. 100 parts of water dissolve about 50 parts of zinc sulphate in the cold, and nearly 100 at the boiling-point. Zinc sulphate is employed for the preparation of brass and zinc baths.

Recognition.—By mixing zinc sulphate solution with acetic acid and conducting sulphuretted hydrogen into the mixture, a white precipitate of zinc sulphide is formed. A slight content of iron is recognized by the zinc sulphate solution, made alkaline by ammonia, giving with ammonium sulphide a somewhat colored precipitate instead of a pure white one. However, a slight content of iron does no harm.

55. *Nickel sulphate.*—Beautiful dark green crystals, readily soluble in water, the solution exhibiting a green color. On heating the crystals to above 536° F., yellow anhydrous nickel sulphate remains behind. Like the double salt described below, it serves for the preparation of nickel baths and for coloring zinc.

Recognition.—By compounding the solution with ammonia the green color passes into blue. Potassium carbonate precipitates pale green basic nickel carbonate, which dissolves on adding ammonia in excess, the solution showing a blue color. A content of copper is recognized by the separation of black-brown copper sulphide on introducing sulphuretted hydrogen into the heated solution previously strongly acidulated with hydrochloric acid.

56. *Nickel-ammonium sulphate.*—It forms green crystals of a somewhat paler color than nickel sulphate. This salt dissolves with more difficulty than the preceding, 100 parts of water dissolving only 5.5 parts of it. It is used for the same purposes as the nickel sulphate, and is also recognized in the same manner.

57. *Cobalt sulphate.*—Crimson crystals of a sharp metallic taste, which are constant in the air and readily dissolve in water, the solution showing a red color. By heating, the crystals lose their water of crystallization without, however, melting, and become thereby transparent and rose-colored. The salt is used for cobalt baths for electro-cobalting and cobalting by contact.

Recognition.—In the presence of ammoniacal salts, caustic potash precipitates a blue basic salt, which, on heating, changes to a rose-colored hydrate, and by standing for some time in the air to a green-brown hydrate. By mixing a concentrated solution of the salt strongly acidulated with hydrochloric acid with solution of potassium nitrate, a reddish-yellow precipitate is formed.

58. *Cobalt-ammonium sulphate.*—This salt forms crystals of the same color as cobalt sulphate, which, however, dissolve more readily in water.

59. *Sodium sulphite and bisulphite.*—a. *Sodium sulphite.* Clear, colorless, and odorless crystals, which are rapidly transformed into an amorphous powder by efflorescence. The salt readily dissolves in water, the solution showing a slight alkaline reaction due to a small content of sodium carbonate. It is employed in

the preparation of gold, brass, and copper baths, for silvering by immersion, etc.

Recognition.—The solution when mixed with dilute sulphuric acid has an odor of burning sulphur.

b. *Sodium bisulphite.* Small crystals, or more frequently in the shape of a pale yellow powder with a strong odor of sulphurous acid and readily soluble in water. The solution shows a strong acid reaction and loses sulphurous acid in the air. It is employed in the preparation of alkaline copper and brass baths.

Both the sulphite and bisulphite must be kept in well-closed receptacles, as by the absorption of atmospheric oxygen they are converted to sulphate.

VIII. *Nitrates.*

60. *Potassium nitrate* (*saltpetre, nitre*).—It forms large, prismatic crystals, generally hollow, but also occurs in commerce in the form of a coarse powder, soluble in 4 parts of water at a medium temperature. The solution has a bitter, saline taste and shows a neutral reaction. Potassium nitrate melts at a glowing heat, and on cooling congeals to an opaque, crystalline mass. It is employed in the preparation of desilvering baths and for producing a dead lustre upon gold and gilding. For these purposes it may, however, be replaced by the cheaper *sodium nitrate*, sometimes called *cubic nitre* or *Chile saltpetre.*

Recognition.—A small piece of coal when thrown upon melting saltpetre burns fiercely. When a not too dilute solution of saltpetre is compounded with solution of potassium bitartrate saturated at the ordinary temperature, a crystalline precipitate of tartar is formed.

61. *Sodium nitrate* (*cubic nitre or Chile saltpetre*).—Colorless crystals, deliquescent and very soluble in water; the solution shows a neutral reaction. It is used for the same purposes as potassium nitrate.

62. *Mercurous nitrate.*—It forms small, colorless crystals, which are quite transparent and slightly effloresce in the air. On heating they melt and are transformed, with the evolution of yellow-red vapors, into yellow-red mercuric oxide, which, on

further heating, entirely evaporates. With a small quantity of water, mercurous nitrate yields a clear solution; by the further addition of water it shows a milky turbidity, which, however, disappears on adding nitric acid. It is employed for quicking the zincs of the elements and the objects previous to silvering, and for brightening gilding. For the same purposes is also used:—

63. *Mercuric nitrate.*—It is difficult to obtain this salt in a crystallized form. It is generally sold in the form of an oily, colorless liquid, which, in contact with water, separates a basic salt. This precipitate disappears upon the addition of a few drops of nitric acid, and the liquid becomes clear.

Recognition.—A bright ribband of copper dipped in solution of mercurous or mercuric nitrate becomes coated with a white amalgam, which disappears upon heating.

64. *Silver nitrate* (*lunar caustic*).—This salt is found in commerce in three forms: either as crystallized nitrate of silver in thin, rhombic, and transparent plates; or in amorphous, opaque, and white plates of fused nitrate; or in small cylinders of white, or gray or black color, according to the nature of the mould employed, in which form it constitutes the lunar caustic for surgical uses. For our purposes only the pure, crystallized product, free from acid, should be employed. The crystals dissolve readily in water. In making solutions of this and other silver salts, only distilled water should be used; all other waters, owing to the presence of chlorine, produce a cloudiness or even a distinct precipitate of silver chloride. In the heat the crystals melt to a colorless, oily fluid, which, on cooling, congeals to a crystalline mass. Silver nitrate is employed in the preparation of chloride and cyanide of silver for silver baths; the solution in potassium cyanide may also be used for silver baths. The alcoholic solution is employed for metallizing moulds.

Recognition.—Hydrochloric acid and common salt solution precipitate from silver nitrate solution silver chloride, which becomes black on exposure to the light, and is soluble in ammonia.

IX. *Phosphates and Pyrophosphates.*

65. *Sodium phosphate.*—Large, clear crystals, which readily effloresce, and whose solution in water shows an alkaline reaction. It is employed in the preparation of gold baths and for the production of metallic phosphates for soldering.

Recognition.—The dilute solution compounded with silver nitrate yields a yellow precipitate of silver phosphate.

66. *Sodium pyrophosphate.*—It forms white crystals, which are not subject to efflorescence, and are soluble in 6 parts of water at a medium temperature; the solution shows an alkaline reaction. Sodium pyrophosphate also occurs in commerce in the form of an anhydrous white powder, though it may here be said that the directions for preparing baths refer to the crystallized salt. It is employed in the preparation of gold, nickel-bronze, and tin baths.

Recognition.—The dilute solution compounded with silver nitrate yields a *white* instead of a *yellow* precipitate.

67. *Ammonium phosphate.*—A colorless crystalline powder quite readily soluble in water; the solution should be as neutral as possible. A salt smelling of ammonia, as well as one showing an acid reaction, should be rejected. It is employed in the preparation of platinum baths.

X. *Salts of the Organic Acids.*

68. *Potassium bitartrate* (*cream of tartar*).—The pure salt forms small transparent crystals of an acid taste, and slightly soluble in water. The commercial crude tartar or *argol*, which is a by-product in the wine industry, forms gray or dirty red crystalline crusts. In a finely powdered state, purified tartar is called *cream of tartar*. It is employed for the preparation of the whitening silver baths, for those of tin, and for the silvering paste by friction.

69. *Potassium sodium tartrate* (*Rochelle or Seignette salt*).—Clear colorless crystals, constant in the air, of a cooling bitter saline taste, and soluble in 2.5 parts of water of a medium temperature. The solution shows a neutral reaction. This salt is

employed in the preparation of copper baths free from cyanide, as well as of nickel and cobalt baths, which are to be decomposed in the single cell apparatus.

Recognition.—By the addition of acetic acid the solution yields an abundant precipitate of tartar.

70. *Antimony-potassium tartrate* (*tartar emetic*).—A white crystalline substance, of which 100 parts of cold water dissolve 5 parts, while a like volume of hot water dissolves 50 parts. The solution shows a slightly acid reaction. The only use of this salt is for the preparation of antimony baths.

Recognition.—The solution compounded with sulphuric, nitric, or oxalic acid yields a white precipitate, insoluble in an excess of the cold acid. Sulphuretted hydrogen imparts to the dilute solution a red color. Hydrochloric acid effects a precipitate, which is redissolved by the acid in excess.

71. *Copper acetate* (*verdigris*).—It is found in the market in the form of dark green crystals showing an acid reaction, or of a neutral bright green powder.

The crystallized copper acetate forms opaque dark green prisms, which readily effloresce, becoming thereby coated with a pale green powder; they dissolve with difficulty in water, but readily in ammonia, forming a solution of a blue color, as well as in potassium cyanide and alkaline sulphites.

The neutral copper acetate forms a blue-green crystalline powder, imperfectly soluble in water, but readily soluble in ammonia, forming a solution of a blue color.

Copper acetate is used for preparing copper and brass baths, for the production of artificial patinas, for coloring, gilding, etc.

72. *Lead acetate* (*sugar of lead*).—Colorless lustrous prisms or needles of a nauseous sweet taste and poisonous. The crystals effloresce in the air, melt at 104° F., and are readily soluble in water, yielding a slightly turbid solution. Lead acetate is employed for preparing lead baths (Nobili's rings) and for coloring copper and brass.

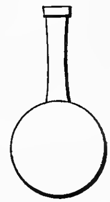
Recognition.—By compounding lead acetate solution with potassium chromate solution, a heavy yellow precipitate of lead chromate is formed.

73. *Sodium citrate.*—Colorless crystals, presenting a moist appearance, which are readily soluble in water; the solution should show a neutral reaction. This salt is employed in the preparation of the platinum bath according to Böttger's formula.

B. *Various Apparatus and Instruments.*

Glass balloons and flasks.—These are spheres of thin blown glass, Fig. 131, with necks of various dimensions in length and diameter. They are employed for heating acids, dissolving metals, and a great many other uses. They should be placed upon triangular supports of iron and at a certain distance from the fire, from the direct action of which they are to be protected by the intervention of a piece of wire gauze or its equivalent. The thinner they are the more easily they bear sudden changes of temperature. They are preferable to porcelain evaporating dishes for dissolving gold, because there is much less danger of losing a part of the product by spurting.

Fig. 131.



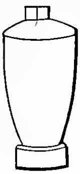
Evaporating dishes or capsules.—These are usually vessels of porcelain, and are intended to bear a high temperature. The best are thin and uniformly so. Like glass flasks, they should be supported above the fire upon an iron stand and wire gauze. As far as practicable they should be gradually heated and cooled. When taken from the fire they should be placed upon rings made of plaited straw. They are made with or without lips, and some have a socket for a wooden handle. Glass evaporating dishes are not durable.

Glass jars.—These are glass vessels, generally cylindrical, closed at one end, and of different capacities.

They are employed for small gilding, silvering, and electroplating baths in the cold. They are handy and serviceable for amateurs, because their transparency permits the progress of the operation to be observed at all times.

Crucibles.—These are vessels, the shape of which is generally an inverted truncated cone, Fig. 132, the smaller end being closed,

Fig. 132.

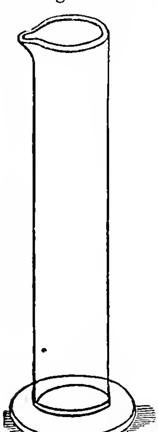


and the larger open. Sometimes the opening is triangular.

Crucibles are made of many kinds of materials: metals, refractory clay, stoneware, porcelain, plumbago or graphite, etc. They are generally provided with a cover of the same material, and are raised above the grate bars of the furnace by means of bricks or cylinders of clay. Metallic crucibles may be heated rapidly, but the others require to have their temperature raised gradually and carefully. They are employed for the preparation of many salts, for the fusion of metals, etc. Non-metallic crucibles are rarely used for more than one operation.

Hydrometers.—These are glass instruments resembling thermometers in outward appearance, but having a large bulb near the bottom. They are used for testing the specific gravity of liquids, or, in other words, to test their density as compared with that of pure water. The liquid to be tested may be placed in a narrow glass jar, Fig. 133, together with the hydrometer, or may be contained in any other vessel. The instrument floats in the liquid to be tested, with its bulb below the surface and its stem standing above the surface. This stem is graded into degrees similar to that of a thermometer, and shows the depth of the bulb beneath the surface. In pure water the bulb sinks down to the 0° mark, or to 1.000 as marked on some scales, 1.000 being taken to represent the density of water at a temperature of 60° F. As the density of water increases by the addition of salts or of liquids having a greater density than water, the bulb is forced upwards, and the scale then registers so many degrees greater density than water.

Fig. 133.



Three differently graduated hydrometers are in use, viz., hydrometers graded to read direct the specific gravity of liquids in comparison with that of water, taking this as represented by 1.000; hydrometers graded by a scale adopted by Mr. W. Twaddell, and known as Twaddell's hydrometers; and hydrometers graded by a scale adopted by

M. Baumé, and named Baumé's hydrometers. The difference between the three gradings is shown in the following table :—

Table showing readings of different hydrometers.

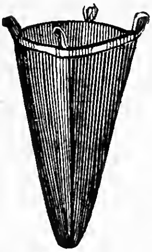
Specific gravity.	Baumé.	Twaddell.	Specific gravity.	Baumé.	Twaddell.
.817°	40°	—	1.250°	—	50°
.827	38	—	1.263	30°	—
.837	36	—	1.300	—	60
.847	34	—	1.321	35	—
.856	32	—	1.350	—	70
.871	30	—	1.385	40	—
.880	28	—	1.400	—	80
.892	26	—	1.450	—	90
.903	24	—	1.454	45	—
.915	22	—	1.500	—	100
.928	20	—	1.532	50	—
.942	18	—	1.550	—	110
.955	16	—	1.600	—	120
.970	14	—	1.618	55	—
.985	12	—	1.650	—	130
1.000	0° or 10	0°	1.700	—	140
1.036	5	—	1.714	60	—
1.050	—	10	1.750	—	150
1.075	10	—	1.800	—	160
1.100	—	20	1.823	65	—
1.116	15	—	1.850	—	170
1.150	—	30	1.900	—	180
1.161	20	—	1.946	70	—
1.200	—	40	1.950	—	190
1.210	25	—			

It will be seen that every degree Twaddell represents 0.005° in the specific gravity hydrometer, and every 10° represents 0.050°. To convert degrees Baumé into readings showing direct specific gravity, subtract the readings on Baumé's scale from the number 144, and divide this by the difference. For example, $144 - 66 = \frac{144}{78} = 1.846°$, the specific gravity of a liquid registering 66° on a Baumé hydrometer. Baumé has one hydrometer for liquids lighter than water (the readings of which are given in the first 16 sets of figures in the foregoing table), and one for liquids heavier than water.

Filters.—Filtering a solution, a bath, or any other liquor, consists in causing it to pass through a permeable substance, the pores or meshes of which are sufficiently close to retain all the undissolved substances, which are thus separated from the liquid part.

Filters are of very different materials and shapes. Cloth, muslin, etc., are coarse filters or strainers, made in the form of pockets. Their filtering power is considerably improved by covering them with a layer of sand, wool, boneblack, etc. These latter substances themselves, properly supported, will act as filters.

Fig. 134.

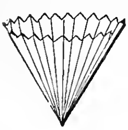


Felted wool (generally rabbit's hair) is made in the shape of a conical pocket (Fig. 134), but is suited only for neutral substances. Alkalies destroy it rapidly.

Concentrated acids are filtered through *amianthus*, or *asbestos*, compressed in the neck of a glass funnel upon broken fragments of glass.

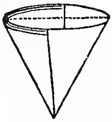
The most useful filtering material, however, is unsized paper. This filter (Fig. 135) is prepared by folding diagonally a square piece of porous paper, which thus prepared forms a triangle. This is again folded in half. Then, beginning at one edge, smaller folds are made alternately to the right and to the left, but all converging towards the point, like a fan. The filter is now partially opened, trimmed on top, and introduced into the funnel, care being had that all the projecting edges rest against it.

Fig. 135.



If it be feared that the filter will not resist the weight of the liquid, the point is twisted to the left or to the right, and while it is still held between two fingers of the left hand, the whole filter is inverted, so that the inward folds become the outward ones. A filter with such a rounded point is better supported in the funnel, and filters more rapidly.

Fig. 136.



This method is preferable for rapid filtration; but if it is desired to recover precipitates, the filter represented by Fig. 136 is more suitable. A circular sheet of paper is twice doubled up, and by carefully opening it three thicknesses of paper are laid on one side, leaving one single thickness on the other side.

Siphons.—The most simple and handy siphon, in many cases, is a piece of lead pipe bent so as to have two unequal branches, the smaller of which plunges into the liquid to be drawn off. A section of India-rubber tube may be employed for similar purposes.

But as these materials may be chemically acted upon by various solutions, glass siphons are used, with or without a suction tube (Figs. 137 and 138).

Fig. 137.

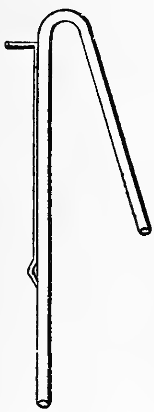
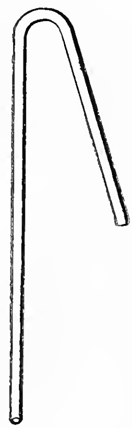


Fig. 138.



For siphoning corrosive solutions which cannot be touched with the fingers, a siphon with a suction tube is used (Fig. 137). The shorter leg is plunged into the liquid and the longer one closed with the finger or an India-rubber pad pressed against it; then, with the mouth, suction should be carefully applied at the lateral suction tube until the liquid fills the longer leg.

If there be any danger of inhaling a poisonous vapor, the action of the mouth may be replaced by an India-rubber ball fastened to the suction tube. The longer branch of the siphon is closed as before, and the ball compressed in order to remove the air. By its elasticity the ball resumes its former volume, thus producing a suction which starts the siphon in action.

Stirring rods.—These are rods made of various materials, and are employed for mixing together liquids or pastes, or liquids and

pastes, or solids with liquids, or various solids in the dry state. Their length and thickness should be suited to the volumes to be mixed.

Suitable stirring rods are those which have no chemical action upon the substances with which they are brought in contact; neither should they become impregnated with them. Rods of glass, stoneware, or porcelain are decidedly the best. Wood and most metals should be avoided, because the former is absorbent and the latter are corroded and easily oxidized.

The operator should always have near at hand a complete assortment of glass stirrers of various sizes, and with fused or rounded ends, in order not to scratch the vessels in which he operates.

CHAPTER XVIII.

USEFUL TABLES.

Table of elements with their symbols, atomic weights, and specific gravities.

Name.	Symbol.	Atomic weight.	Specific gravity.	Name.	Symbol.	Atomic weight.	Specific gravity.
Aluminium .	Al	27.4	2.67	Molybdenum	Mo	96	8.60
Antimony . .	Sb	122	6.72	Nickel . .	Ni	58	8.8
Arsenic . .	As	75	5.63	Niobium . .	Nb	94	6.67
Barium . .	Ba	137	4.00	Nitrogen . .	N	14	0.972
Beryllium . .	Be	9.3	2.10	Osmium . .	Os	199.4	21.3
Bismuth . .	Bi	208	9.799	Oxygen . .	O	16	1.088
Boron . . .	B	11	2.68	Palladium .	Pd	106.6	11.8
Bromine . .	Br	80	2.97	Phosphorus .	P	31	1.84
Cadmium . .	Cd	112	8.67	Platinum . .	Pt	197.4	21.15
Cæsium . .	Cs	133	—	Potassium .	K	39.1	8.865
Calcium . .	Ca	40	3.10	Rhodium . .	Rh	104.4	12.10
Carbon . .	C	12	3.50	Rubidium .	Rb	85.4	1.50
Cerium . .	Ce	92	—	Ruthenium .	Ru	104.4	11.40
Chlorine . .	Cl	35.5	2.45	Selenium . .	Se	79.4	4.28
Chromium .	Cr	52	6.81	Silicium . .	Si	28	2.49
Cobalt . . .	Co	58.8	8.50	Silver . . .	Ag	108	10.50
Copper . . .	Cu	63.4	8.88	Sodium . .	Na	23	0.972
Didymium .	D	95	—	Strontium .	Sr	87.5	2.54
Erbium . .	E	112.6	—	Sulphur . .	S	32	2.045
Fluorine . .	F	19	—	Tantalum .	Ta	182	10.78
Gold . . .	Au	197	19.50	Tellurium .	Te	128	6.18
Hydrogen . .	H	1	0.069	Thallium . .	Tl	204	11.86
Indium . .	In	75.6	—	Thorinum .	Th	231	7.70
Iodine . . .	I	127	4.98	Tin	Sn	118	7.29
Iridium . .	Ir	197.4	21.15	Titanium .	Ti	50	5.30
Iron . . .	Fe	56	7.70	Tungsten .	W	184	19.10
Lanthanum .	La	92	—	Uranium . .	U	120	18.40
Lead . . .	Pb	207	11.38	Vanadium .	V	51.3	5.50
Lithium . .	Li	7	0.59	Yttrium . .	Y	68	—
Magnesium .	Mg	24	1.74	Zinc . . .	Zn	65	6.86
Manganese .	Mn	55	8.00	Zirconium .	Zr	89.6	4.20
Mercury . .	Hg	200	13.59				

Table of chemical and electro-chemical equivalents.

Name of substance.	Symbol.	Specific gravity.	Chemical equivalent.	Electro-chemical equivalent. Milligrammes.	Weights decomposed by 1 ampère in 1 hour. In grammes.
Hydrogen . . .	H	1	1	0.01036	0.0375
Aluminium . .	Al	2.6	13.7	0.14250	0.5137
Antimony . . .	Sb	6.8	122	1.26880	4.5750
Arsenic . . .	As	5.7	75	0.78000	2.8125
Cobalt . . .	Co	8.7	29 5	0.30680	1.1062
Copper . . .	Cu	8.8	31.8	0.33070	1.1925
Gold	Au	19.2	98.3	1.02230	3.6862
Iron	Fe	7.5	28	0.29120	1.0500
Lead	Pb	11.3	103.5	1.07640	3.8812
Nickel . . .	Ni	8.6	29.5	0.30680	1.1062
Platinum . . .	Pt	21.2	98.6	1.02540	3.6975
Silver . . .	Ag	10.5	108	1.12320	4.0500
Tin	Sn	7.3	32.7	0.34010	1.2262
Zinc	Zn	7.2	59	0.61360	2.2125

With the assistance of this table it can be calculated how long a measured surface has to remain in the bath in order to acquire a deposit of determined weight with the most suitable current density. Suppose the time is to be determined which a square decimetre of surface has to remain in the nickel bath in order to acquire a deposit of $\frac{1}{10}$ millimetre thick with a current density of 0.5 ampère. First calculate the weight of the deposit by multiplying the surface in square millimetres with the thickness and specific gravity. One square decimetre is equal to 10,000 square millimetres, which, multiplied by $\frac{1}{10}$ millimetre, gives as a product 1000, which, multiplied by the specific gravity of nickel—8.6—gives 8600 milligrammes = 8.6 grammes. Since, for the regular deposit per square decimetre, a current density of 0.5 ampère is required, and 1 ampère deposits, according to the above table, 1.1062 grammes in 1 hour, $\frac{1}{2}$ ampère deposits 0.5331 gramme in 1 hour, and, therefore, about 16 hours will be required for the deposition of 8.6 grammes.

According to this example, the time, for instance, can also be calculated which one, two, or more dozen of knives and forks or spoons, which are to have a deposit of silver of a determined weight, must remain in the bath when the current density is known. Suppose 50 grammes of silver are to be deposited upon 1 dozen of

spoons, and the most suitable current density is 0.2 ampère per square decimetre; if the surface of 1 spoon represents 1.10 square decimetres, the surface of 1 dozen spoons of equal size is 13.2 square decimetres. Hence, they require $13.2 \times 0.2 = 2.64$ ampères; now, since 1 ampère deposits in one hour 4.05 grammes of silver, 2.64 ampères deposit in the same time 10.7 grammes of silver, and with this current the dozen spoons must remain about $4\frac{3}{4}$ hours in the bath for the deposition of 50 grammes of silver upon this surface.

Table showing the value of equal current volumes as expressed in ampères per square decimetre, per square foot, and per square inch of electrode surface.

Ampères per square decimetre.	= Ampères per square foot.	= Ampères per square inch.	Ampères per square decimetre.	= Ampères per square foot.	= Ampères per square inch.	Ampères per square decimetre.	= Ampères per square foot.	= Ampères per square inch.
0.05	0.46	0.0032	0.8	7.43	0.0516	6.20	57.6	0.4
0.054	0.5	0.0035	0.86	8	0.0555	6.46	60	0.4167
0.077	0.72	0.005	0.9	8.36	0.0581	7	65.0	0 4516
0.1	0.93	0.0064	0.93	8.64	0.06	7.53	70	0.4861
0.11	1	0.0069	0.97	9	0.0625	7.75	72.0	0.5
0.15	1.44	0.01	1	9.29	0.0645	8	74.3	0.5161
0.2	1.86	0.0129	1.08	10	0.0694	8.61	80	0.5555
0.22	2	0.0139	1.09	10.08	0.07	9	83.6	0.5806
0.3	2.79	0.0193	1.24	11.52	0.08	9.30	86.4	0.6
0.31	2.88	0.02	1.39	12.96	0.09	9.69	90	0.6250
0.32	3	0.0208	1.55	14.4	0.1	10	92.9	0.6452
0.4	3.71	0.0258	2	18.6	0.1290	10.76	100	0.6944
0.43	4	0.0278	2.15	20	0.1389	10.85	100.8	0.7
0.46	4.32	0.03	3	27.9	0.1935	12.40	115.2	0.8
0.5	4.64	0.0323	3.10	28.8	0.2	13.95	129.6	0.9
0.54	5	0.0348	3.23	30	0 2083	15.50	144.0	1
0.6	5.57	0 0387	4	37.1	0.2581	20	185.8	1.2903
0.62	5.76	0.04	4.30	40	0.2778	21.53	200	1.3889
0.65	6	0.0417	4.60	43.2	0.3	30	278.7	1.9355
0.7	6.50	0.0452	5	46.4	0.3226	31.0	288	2
0.75	7	0.0486	5.38	50	0.3478	32.3	300	2.0833
0.77	7.20	0.05	6	55.7	0.3871	46.5	432.0	3

By this table the current density may be expressed in ampères per square decimetre, square foot, or square inch, any of them being given. Thus a current of 1 ampère per square decimetre has the same electrolytic value as one of 9.29 ampères per square foot or 0.0645 per square inch. To find the value of intermediate

numbers, not shown above, add together the various numbers representing the hundreds, tens, units, and decimals of the given quantity. Thus 27.5 ampères per square decimetre (=20+7+5) are equivalent to 185.8+65+4.64=255.44 ampères per square foot, or 1.2903+0.4516+0.0323=1.7742 ampères per square inch.

Table showing the specific electrical resistances of different sulphuric acid solutions at various temperatures (Fleeming Jenkin).*

Specific gravity of acid.	Temperatures (Fahrenheit).							
	32°	39.2°	46.4°	53.6°	60.8°	68°	75.2°	82 4°
1.10	1.37	1.17	1.04	0.92	0.84	0.79	0.74	0.71
1.20	1.33	1.11	0.93	0.79	0.67	0.57	0.49	0.41
1.25	1.31	1.09	0.90	0.74	0.62	0.51	0.43	0.36
1.30	1.36	1.13	0.94	0.79	0.66	0.56	0.47	0.39
1.40	1.69	1.47	1.30	1.16	1.05	0.96	0.89	0.84
1.50	2.74	2.41	2.13	1.89	1.72	1.61	1.32	1.43
1.60	4.32	4.16	3.62	3.11	2.75	2.46	2.21	2.02
1.70	9.41	7.67	6.25	5.12	4.23	3.57	3.07	2.71

Table showing the specific electrical resistances of different copper sulphate solutions at various temperatures (Fleeming Jenkin).*

No. of parts of copper sulphate dissolved in 100 parts of water.	Temperatures (Fahrenheit).						
	57.2°	60.8°	64.4°	68°	75.2°	82.4°	86°
8	45.7	43.7	41.9	40.2	37.1	34.2	32.9
12	36.3	34.9	33.5	32.2	29.9	27.9	27.0
16	31.2	30.0	28.9	27.9	26 1	24.6	24.0
20	28.5	27.5	26.5	25.6	24.1	22.7	22.2
24	26.9	25.9	24.8	23.9	22.2	20.7	20.0
28	24.7	23.4	22.1	21.0	18.8	16.9	16.0

* By the term "specific resistance," in the above tables, is meant the absolute resistance in ohms of a column of the liquid 1 square centimetre in cross-section and 1 centimetre long; in other words, it is the resistance of a cubic centimetre of the liquid. The diminution of resistance accompanying a rise of temperature should be especially marked.

Table of the electro-motive force of elements.

Name of element.	Constitution.	Electro-motive force in volts.	Authority.
Wollaston . .	Amalgamated zinc and copper in dilute sulphuric acid (1 : 12).	0.886 0.861 0.719	Clark and Sabine. Sprague. De la Rive.
Smee . . .	Amalgamated zinc in sulphuric acid; platinized silver, or platinum in sulphuric acid (1 : 12).	1.098 1.107 0.541 1.192	Clark and Sabine. Sprague. De la Rive. Naclari.
Daniell . .	Amalgamated zinc in sulphuric acid (1 : 4); copper in saturated solution of copper sulphate.	1.079 do. do. do.	Clark and Sabine. Sprague. De la Rive. Naclari.
do. . . .	Zinc in dilute sulphuric acid (1 : 12); copper as above.	0.978 0.98	Clark and Sabine. Du Moncel.
Leclanché . .	Zinc in sal ammoniac, carbon with manganese peroxide in sal ammoniac.	1.481 1.561 1.942 1.259	Clark and Sabine. Sprague. De la Rive. Beetz.
do. . . .	Zinc in solution of common salt; carbon with manganese peroxide in common salt solution.	1.493 1.360 1.34	Sprague. Naclari. Du Moncel.
Marie Davy .	Zinc in dilute sulphuric acid (1 : 12); carbon in mercurous sulphate.	1.524 1.542 1.482 1.440	Clark and Sabine. Sprague. Naclari. Du Moncel.
Grove . . .	Zinc in dilute sulphuric acid (1 : 12); platinum in fuming nitric acid.	1.956	Clark and Sabine.
do. . . .	Zinc as above; platinum in nitric acid of 1.38 sp. gr.	1.524 1.542	Clark and Sabine. Sprague.
Bunsen . . .	Zinc as above; carbon in fuming nitric acid.	1.964 1.95	Clark and Sabine. Du Moncel.
do. . . .	Zinc as above; carbon in nitric acid of 1.38 sp. gr.	1.888 1.941 1.880	Clark and Sabine. Beetz. Naclari.
do. . . .	Zinc as above; carbon in bichromate of potassium.	2.028 1.905 2.120	Clark and Sabine. Sprague. Naclari.
Grenet . . .	Zinc and carbon in bichromate of potassium.	1.825	Naclari.

Table showing the solubility of various substances.

Substances of which 1 part is soluble	in water of 59° F.	in water of 212° F.	in alcohol of 59° F.
Alum	6.5	0.3	insoluble.
Ammonium carbonate	4.0	decomposes	soluble.
Citric acid	0.75	0.6	soluble.
Copper sulphate (blue vitriol)	5.0	1.3	insoluble.
Ferric chloride	0.6	very soluble	soluble.
Ferrous chloride	0 8	"	soluble.
Ferrous sulphate (green vitriol)	1.5	0.3	insoluble.
Iodine	7000	soluble	readily soluble.
Nickel nitrate	2.0	very soluble	soluble.
" sulphate	3.0	2.0	insoluble.
Potash	0 9	very soluble	insoluble.
" caustic	0.5	"	soluble.
Potassium cyanide	readily soluble	readily soluble	soluble.
" dichromate (red chromate of potash)	10	1.2	insoluble.
Sal ammoniac	3.0	1.4	sparingly soluble.
Silver, citrate	sparingly soluble	sparingly soluble	——
" nitrate	0.8	very soluble	1 part at a boiling heat.
Soda	1.0	0.3	insoluble.
" caustic	2.0	0.5	insoluble.
Sodium bisulphite	soluble	soluble	——
" chloride	2.8	2.5	60
" sulphite	4.0	1.0	insoluble.
Yellow prussiate of potash	4.0	1.0	insoluble.
Zinc chloride	0.3	very soluble	1
" sulphate	2.0	1.0	insoluble.

Table Showing the Composition of the Most Usual Alloys and Solders.

Alloys are combinations or mixtures, effected by the fusion of two or more different metals in definite proportions. The electro-plater employs them so constantly that it is important that he be acquainted with the compositions of the most usual alloys, and that he learn the preparation of several of them, which, like the fusible alloys of Darcet, will often be serviceable.

It is, of course, possible to vary *ad infinitum* the mixtures and the proportions of the component metals given in the following

table, and thus to arrive at an unlimited number of alloys which, on account of slight differences of color, ductility, sonorousness, etc., have received a great variety of names.*

1. *Alloys.*

	Copper.	Zinc.	Tin.	Lead.	Nickel.	Bismuth.	Antimony.	Arsenic.	Iron.
	Parts.								
Argentan, elastic	57.4	25	—	—	13	—	—	—	9
Brass for articles worked with the hammer	70	30	—	—	—	—	—	—	—
" for turning	66	32	—	2	—	—	—	—	—
" for decorating purposes	60	40	—	—	—	—	—	—	—
" for sheet	75	25	—	—	—	—	—	—	—
Britannia	4	—	70.5	—	—	—	25.5	—	—
"	10	6	22	—	—	—	62	—	—
Bronze for bells	80	—	20	—	—	—	—	—	—
" for larger bells	78	—	22	—	—	—	—	—	—
" for smaller bells	42	—	58	—	—	—	—	—	—
" for clocks	75	—	25	—	—	—	—	—	—
" for cymbals	80	—	20	—	—	—	—	—	—
" for gongs	100	—	25	—	—	—	—	—	—
" for medals	100	—	8	—	—	—	—	—	—
" for large ordnance	90	—	10	—	—	—	—	—	—
" for small ordnance	93	—	7	—	—	—	—	—	—
" for statues	84	—	16	—	—	—	—	—	—
" "	84	11	4	1	—	—	—	—	—
" "	82	—	18	—	—	—	—	—	—
Chrysochalk	80	10.5	8	—	—	—	—	—	—
Darcet's fusible alloy	—	—	4	4	—	8	—	—	—
" " "	—	—	3	5	—	8	—	—	—
" " "	—	—	2	3	—	5	—	—	—
German silver	50	3.5	—	—	4	—	—	—	—
" "	53	31.25	—	—	15.75	—	—	—	—
" "	8	3.5	—	—	3	—	—	—	—
" "	4	1	—	—	1	—	—	—	—
" "	55	17	2	—	23	—	—	—	3
Potin (French yellow brass)	11.9	24.9	1.2	0.2	—	—	—	—	—
Similor	100	12	—	—	—	—	—	—	—
Talmi gold	86.6	12.6	2.4	1.2	—	—	—	—	—
Telescope mirrors (reflectors)	100	—	50	—	—	—	—	1	—
Tombac	80	20	—	—	—	—	—	—	—
" pale	76	24	—	—	—	—	—	—	—
" red	88	12	—	—	—	—	—	—	—
" resembling gold	84	16	—	—	—	—	—	—	—

* For a full description of alloys and amalgams see "The Metallic Alloys," edited by W. T. Brannt. Philadelphia. Henry Carey Baird & Co. 1889.

2. *Solders.*

a. *Soft Solder.*

Tin.	Lead.	Melts at degrees F.	Tin.	Lead.	Melts at degrees F.
Parts.			Parts.		
1	25	558°	1½	1	334°
1	10	541	2	1	340
1	5	511	3	1	356
1	3	482	4	1	365
1	2	441	5	1	378
1	1	370	6	1	381

b. *Hard Solder.*

	Brass.	Zinc.	Tin.
	Parts.		
Very refractory	85.42	12.58	—
" "	7	1	—
Refractory	3	1	—
"	4	1	—
Readily fusible	5	2	—
"	5	4	—
Half white	12	5	1
"	44	20	2
White	40	2	8
"	22	2	4
"	18	12	30
Very ductile	78.25	17.25	—

c. *Silver Solder.*

	Silver.	Copper.	Brass.	Tin.	Zinc.
	Parts.				
Brass silver solder	1	—	1	—	—
Hard silver solder	4	1	—	—	—
Very hard solder	40	10	—	—	—
Middling hard solder	40	10	40	10	—
Soft silver solder	32	—	32	2	—
Silver solder for cast iron . .	20	30	—	—	10
Silver solder for steel	30	10	—	—	—

d. *Gold Solder.*

	Gold.	Silver.	Copper.	Zinc.
	Parts.			
Hard solder for fineness 750 . .	9	2	1	—
Soft " " " 750 . .	12	7	3	—
Solder for fineness 583 . . .	3	2	1	—
" " " 583 . . .	2	0.5	0.5	—
" " " less than 583 .	1	2	1	—
" " " " " " .	1	2	—	—
" " " " " " .	1	—	2	—
Solder readily fusible . . .	11.94	54.74	28.17	5.01
" " " for yellow gold	10	5	—	1

Table of the melting-points of some metals.

Metals.	Degrees, Fahrenheit.	Metals.	Degrees, Fahrenheit.
Tin	458.6	Gold	2372
Lead	599.4	Iron, crude . .	2912 to 3092
Zinc	773.6	Nickel . . .	2912
Antimony . . .	809.6	Steel . . .	3092 to 3452
Brass . . .	1859	Iron, bar . . .	3452 to 3812
Copper . . .	1994		

Table of high temperatures.

Description.	Degrees, Fahrenheit.	Description.	Degrees, Fahrenheit.
Incipient red heat .	977	An orange-red heat .	1700
A red heat . .	980	A bright red heat .	1873
A dull red heat visible in daylight . .	1000	A dull white heat .	1996
Heat of a common fire	1140	A white heat . .	3000
A full red heat . .	1200	Heat of a good blast furnace . . .	3300
Dull red heat . .	1310		

Table of the specific gravity and content of solutions of potassium carbonate at 57.2° Fahrenheit, according to Gerlach.

Potassium carbonate, per cent.	Specific gravity.	Potassium carbonate, per cent.	Specific gravity.	Potassium carbonate, per cent.	Specific gravity.
2	1.01829	20	1.19286	38	1.39476
4	1.03658	22	1.21402	40	1.41870
6	1.05513	24	1.23517	42	1.44338
8	1.07396	26	1.25681	44	1.46807
10	1.09278	28	1.27893	46	1.49314
12	1.11238	30	1.30105	48	1.51861
14	1.13199	32	1.32417	50	1.54408
16	1.15200	34	1.34729	52	1.57048
18	1.17243	36	1.37082	52.024	1.57079

Table showing the specific gravity of sulphuric acid at 59° F., according to Kolb.

Degrees, Baumé.	Specific gravity.	100 parts by weight contain		One litre contains in kilogrammes		Degrees, Baumé.	Specific gravity.	100 parts by weight contain		One litre contains in kilogrammes	
		SO_3	H_2SO_4.	SO_3.	H_2SO_4.			SO_3.	H_2SO_4.	SO_3.	H_2SO_4.
0	1.000	0.7	0.9	0.007	0.009	34	1.308	32.8	40.2	0.429	0.526
1	1.007	1.5	1.9	0.015	0.019	35	1.320	33.8	41.6	0.447	0.549
2	1.014	2.3	2.8	0.023	0.028	36	1.332	35.1	43.0	0.468	0.573
3	1.022	3.1	3.8	0.032	0.039	37	1.345	36.2	44.4	0.487	0.597
4	1.029	3.9	4.8	0.040	0.049	38	1.357	37.2	45.5	0.505	0.617
5	1.037	4.7	5.8	0.049	0.060	39	1.370	38.3	46.9	0.525	0.642
6	1.045	5.6	6.8	0.059	0.071	40	1.383	39.5	48.3	0.546	0.668
7	1.052	6.4	7.8	0.067	0.082	41	1.397	40.7	49.8	0.569	0.696
8	1.060	7.2	8.8	0.076	0.093	42	1.410	41.8	51.2	0.589	0.722
9	1.067	8.0	9.8	0.085	0.105	43	1 424	42.9	52.8	0.611	0.749
10	1.075	8.8	10.8	0.095	0.116	44	1.438	44.1	54.0	0.634	0.777
11	1.083	9.7	11.9	0.105	0.129	45	1.453	45.2	55.4	0.657	0.805
12	1.091	10.6	13.0	0.116	0.142	46	1.468	46.4	56.9	0.681	0.835
13	1.100	11.5	14.1	0.126	0.155	47	1.483	47.6	58.3	0.706	0.864
14	1.108	12.4	15.2	0.137	0.168	48	1.498	48.7	59.6	0.730	0.893
15	1.116	13.2	16.2	0.147	0.181	49	1.514	49.8	61.0	0.754	0.923
16	1.125	14.1	17.3	0.159	0.195	50	1.530	51.0	62.5	0.780	0.956
17	1.134	15.1	18.5	0.172	0.210	51	1.540	52.2	64.0	0.807	0.990
18	1.142	16.0	19.6	0.183	0.224	52	1.563	53.5	65.5	0.836	1.024
19	1.152	17.0	20.8	0.196	0.233	53	1.580	54.9	67.0	0.867	1.059
20	1.162	18.0	22.2	0.209	0.258	54	1.597	56.0	68.6	0.894	1.095
21	1.171	19.0	23.3	0.222	0.273	55	1.615	57.1	70.0	0.922	1.131
22	1.180	20.0	24.5	0.236	0.289	56	1.634	58.4	71.6	0.954	1.170
23	1.190	21.1	25.8	0.251	0.307	57	1.652	59.7	73.2	0.986	1.210
24	1.200	22.1	27.1	0.265	0.325	58	1.672	61.0	74.7	1.019	1.248
25	1.210	23.2	28.4	0.281	0.344	59	1.691	62.4	76.4	1.055	1.292
26	1.220	24.2	29.6	0.295	0.361	60	1.711	63.8	78.1	1.092	1.336
27	1.231	25.3	31.0	0.311	0.382	61	1.732	65.2	79.0	1 129	1.384
28	1.241	26.3	32.2	0.326	0.400	62	1.753	66.7	81.7	1.169	1.432
29	1.252	27.3	33.4	0 342	0.418	63	1.774	68.7	84.1	1.219	1.492
30	1.263	28.3	34.7	0.357	0.438	64	1.796	70.6	86.5	1.268	1.554
31	1.274	29.4	36.0	0.374	0.459	65	1.819	73.2	89.7	1.332	1.632
32	1.285	30.5	37.4	0.392	0.481	66	1.842	81.6	100.0	1.503	1.842
33	1.297	31.7	38.8	0.411	0.503						

Table of the specific gravity and content of nitric acid, according to Kolb.

Degrees, Baumé.	Specific gravity.	100 parts contain at 32° F.		100 parts contain at 59° F.		Degrees, Baumé.	Specific gravity.	100 parts contain at 32° F.		100 parts contain at 59° F.	
		HNO_3.	N_2O_5.	HNO_3.	N_2O_5.			HNO_3.	N_2O_5.	HNO_3.	N_2O_5.
0	1.000	0.0	0.0	0.2	0.1	28	1.242	36.2	31.0	38.6	33.1
1	1.007	1.1	0.9	1.5	1.3	29	1.252	37.7	32.3	40.2	34 5
2	1.014	2.2	1.9	2.6	2.2	30	1.261	39.1	33.5	41.5	35.6
3	1.022	3.4	2.9	4.0	3.4	31	1.275	41.1	35.2	43.5	37.3
4	1.029	4.5	3.9	5.1	4.4	32	1.286	42.6	36.5	45.0	38.6
5	1.036	5.5	4.7	6 3	5.4	33	1.298	44.4	38.0	47.1	40.4
6	1.044	6.7	5.7	7.6	6.5	34	1.309	46.1	39.5	48.6	41.7
7	1.052	8.0	6.9	9.0	7.7	35	1.321	48.0	41.1	50.7	43.5
8	1.060	9.2	7.9	10.2	8.7	36	1.334	50.0	42.9	52.9	45.3
9	1.067	10.2	8.7	11.4	9.8	37	1.346	51.9	44.5	55.0	47.1
10	1.075	11.4	9.8	12.7	10.9	38	1.359	54.0	46.3	57.3	49.1
11	1.083	12.6	10.8	14.0	12.0	39	1.372	56.2	48.2	59.6	51.1
12	1.091	13.8	11.8	15.3	13.1	40	1.384	58.4	50.0	61.7	52.9
13	1.100	15.2	13.0	16.8	14.4	41	1.398	60.8	52.1	64.5	55.3
14	1.108	16.4	14.0	18.0	15.4	42	1.412	63.2	54.2	67.5	57.9
15	1.116	17.6	15.1	19.4	16.6	43	1.426	66.2	56.7	70.6	60.5
16	1.125	18.9	16.2	20.8	17.8	44	1.440	69.0	59.1	74.4	63.8
17	1.134	20.2	17.3	22.2	19.0	45	1.454	72.2	61.9	78.4	67.2
18	1.143	21.6	18.5	23.6	20.2	46	1.470	76.1	65.2	83.0	71.1
19	1.152	22.9	19.6	24.9	21.3	47	1.485	80.2	68.7	87.1	74.7
20	1.161	24.2	20.7	26.3	22.5	48	1.501	84.5	72.4	92.6	79.4
21	1.171	25.7	22.0	27.8	23.8	49	1.516	88.4	75.8	96.0	82.3
22	1.180	27.0	23.1	29.2	25.0	49.5	1.524	90.5	77.6	98.0	84.6
23	1.190	28.5	24.4	30.7	26.3	49.9	1.530	92.2	79.0	100.0	85.71
24	1.199	29.8	25.5	32.1	27.5	50.0	1.532	92.7	79.5	—	—
25	1.210	31.4	26.9	33.8	28 9	50 5	1.541	95.0	81.4	—	—
26	1.221	33.1	28.4	35.5	30.4	51.0	1.549	97.3	83.4	—	—
27	1.231	34.6	29.7	37.0	31.7	51.5	1.559	100.0	85.71	—	—

Table showing the specific gravity of sal ammoniac solutions at 66.2° F., according to Schiff.

Content of the solution, per cent.	Specific gravity.	Content of the solution, per cent.	Specific gravity.	Content of the solution, per cent.	Specific gravity.
1	1.0029	11	1.0322	21	1.0606
2	1.0058	12	1.0351	22	1.0633
3	1.0087	13	1.0380	23	1.0660
4	1.0116	14	1.0409	24	1.0687
5	1.0145	15	1.0438	25	1.0714
6	1.0174	16	1.0467	26	1.0741
7	1.0203	17	1.0495	27	1.0768
8	1.0233	18	1.0523	28	1.0794
9	1.0263	19	1.0551	29	1.0820
10	1.0293	20	1.0579	30	1.0846

Table showing the electrical resistance of pure copper wire of various diameters.

No. of wire, Birmingham wire gauge.	Resistance of 1 foot in ohms.	Number of feet required to give resistance of 1 ohm.	No. of wire, Birmingham wire gauge.	Resistance of 1 foot in ohms.	Number of feet required to give resistance of 1 ohm.
0000	0.0000516	19358	17	0.00316	316.1
000	0.0000589	16964	18	0.00443	225.5
00	0.0000737	13562	19	0.00603	165.7
0	0.0000922	10857	20	0.00869	115.1
1	0.000118	8452.6	21	0.01040	96.2
2	0.000132	7575.1	22	0.01358	73.6
3	0.000159	6300.1	23	0.01703	58.7
4	0.000188	5319.9	24	0.02200	45.5
5	0.000220	4545.9	25	0.02661	37.6
6	0.000258	3870.3	26	0.03286	30.4
7	0.000329	3043.4	27	0.04159	24.0
8	0.000391	2557.1	28	0.05432	18.4
9	0.000486	2057.7	29	0.06300	15.9
10	0.000593	1686.5	30	0.07393	13.5
11	0.000739	1352.5	31	0.10646	9.4
12	0.000896	1116.0	32	0.13144	7.6
13	0.001180	847.7	33	0.16634	6.0
14	0.001546	647.0	34	0.21727	4.6
15	0.002053	487.0	35	0.42583	2.4
16	0.002520	396.8	36	0.66537	1.5

Resistance and conductivity of pure copper at different temperatures.

Centigrade temperature.	Resistance.	Conductivity.	Centigrade temperature.	Resistance.	Conductivity.
0°	1.00000	1.00000	16°	1.06168	.94190
1	1.00381	.99624	17	1.06563	.93841
2	1.00756	.99250	18	1.06959	.93494
3	1.01135	.98878	19	1.07356	.93148
4	1.01515	.98508	20	1.07742	.92814
5	1.01896	.98139	21	1.08164	.92452
6	1.02280	.97771	22	1.08553	.92121
7	1.02663	.97406	23	1.08954	.91782
8	1.03048	.97042	24	1.09365	.91445
9	1.03435	.96679	25	1.09763	.91110
10	1.03822	.96319	26	1.10161	.90776
11	1.04199	.95970	27	1.10567	.90443
12	1.04599	.95603	28	1.11972	.90113
13	1.04990	.95247	29	1.11382	.89784
14	1.05406	.94893	30	1.11782	.89457
15	1.05774	.94541			

Table showing actual diameters in decimal parts of an inch corresponding to the numbers of various wire gauges.

No. of wire gauge.	Roebling.	Brown & Sharpe.	Birmingham or Stubs.	English legal standard.	Old English or London.
000000	.46	—	—	.464	—
00000	.43	—	—	.432	—
0000	.393	.46	.454	.4	.454
000	.362	.40964	.425	.372	.425
00	.331	.3648	.380	.348	.38
0	.307	.32495	.340	.324	.34
1	.283	.2893	.3	.3	.3
2	.263	.25763	.284	.276	.284
3	.244	.22942	.259	.252	.259
4	.225	.20431	.238	.232	.238
5	.207	.18194	.22	.212	.22
6	.192	.16202	.203	.192	.203
7	.177	.14428	.18	.176	.18
8	.162	.12849	.165	.16	.165
9	.148	.11443	.148	.144	.148
10	.135	.10189	.134	.128	.134
11	.120	.09074	.12	.116	.12
12	.105	.08081	.109	.104	.109
13	.092	.07196	.095	.092	.095
14	.08	.06408	.083	.08	.083
15	.072	.05706	.072	.072	.072
16	.063	.05082	.065	.064	.065
17	.054	.04525	.058	.056	.058
18	.047	.0403	.049	.048	.049
19	.041	.03589	.042	.04	.04
20	.035	.03196	.035	.036	.035
21	.032	.02846	.032	.032	.0315
22	.028	.02534	.028	.028	.0295
23	.025	.02257	.025	.024	.027
24	.023	.0201	.022	.022	.025
25	.02	.0179	.02	.02	.023
26	.018	.01594	.018	.018	.0205
27	.017	.01419	.016	.0164	.01875
28	.016	.01264	.014	.0148	.0165
29	.015	.01125	.013	.0136	.0155
30	.014	.01002	.012	.0124	.01375
31	.0135	.00893	.010	.0116	.01225
32	.013	.00795	.009	.0108	.01125
33	.011	.00708	.008	.01	.01025
34	.01	.0063	.007	.0092	.0095
35	.0095	.00561	.005	.0084	.009
36	.009	.005	.004	.0076	.0075

Weight of iron, copper, and brass wire and plates.

(Diameters and thickness determined by American gauge)

No. of gauge.	Size of each No.	Weight of wire per 1000 lineal feet.				Weight of plates per square foot.			
		Wro't iron.	Steel.	Copper.	Brass.	Wro't iron.	Steel.	Copper.	Brass.
	Inch.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
0000	.46000	560.74	566.03	640.51	605.18	17.25	17.48	20.838	19.688
000	.40964	444.68	448.88	507.95	479.91	15.3615	15.5663	18.557	17.533
00	.36480	352.66	355.99	402.83	380.67	13.68	13.8624	16.525	15.613
0	.32486	279.67	282.30	319.45	301.82	12.1823	12.3447	14.716	13.904
1	.28930	221.79	223.89	253.34	239.35	10.8488	10.9934	13.105	12.382
2	.25763	175.89	177.55	200.91	189.82	9.6611	9.7899	11.671	11.027
3	.22942	139.48	140.80	159.32	150.52	8.6033	8.7180	10.393	9.8192
4	.20431	110.62	111.66	126.35	119.38	7.6616	7.7638	9.2552	8.7445
5	.18194	87.720	88.548	100.20	94.666	6.8228	6.9137	8.2419	7.787
6	.16202	69.565	70.221	79.462	75.075	6.0758	6.1568	7.3395	6.9345
7	.14428	55.165	55.685	63.013	59.545	5.4105	5.4826	6.5359	6.1752
8	.12849	43.751	44.164	49.976	47.219	4.8184	4.8826	5.8206	5.4994
9	.11443	34.699	35.026	39.636	37.437	4.2911	4.3483	5.1837	4.8976
10	.10189	27.512	27.772	31.426	29.687	3.8209	3.8718	4.6156	4.3609
11	.090742	21.820	22.026	24.924	23.549	3.4028	3.4482	4.1106	3.8838
12	.080808	17.304	17.468	19.766	18.676	3.0303	3.0707	3.6606	3.4586
13	.071961	13.722	13.851	15.674	14.809	2.6985	2.7345	3.2598	3.0799
14	.064084	10.886	10.989	12.435	11.746	2.4032	2.4352	2.9030	2.7428
15	.057068	8.631	8.712	9.859	9.315	2.1401	2.1686	2.5852	2.4425
16	.050820	6.845	6.909	7.819	7.587	1.9058	1.9312	2.3021	2.1751
17	.045257	5.427	5.478	6.199	5.857	1.6971	1.7198	2.0501	1.937
18	.040303	4.304	4.344	4.916	4.645	1.5114	1.5315	4.8257	1.725
19	.035890	3.413	3.445	3.899	3.684	1.3459	1.3638	1.6258	1.5361
20	.031961	2.708	2.734	3.094	2.920	1.1985	1.2145	1.4478	1.3679
21	.028462	2.147	2.167	2.452	2.317	1.0673	1.0816	1.2893	1.2182
22	.025347	1.703	1.719	1.945	1.838	.95051	.96319	1.1482	1.0849
23	.022571	1.350	1.363	1.542	1.457	.84641	.8577	1.0225	.96604
24	.020100	1.071	1.081	1.223	1.155	.75375	.7638	.91053	.86028
25	.017900	0.8491	0.8571	.9699	0.9163	.67125	.6802	.81087	.76612
26	.015941	0.6734	0.6797	.7692	0.7267	.59775	.60572	.72208	.68223
27	.014195	0.5340	0.5391	.6099	0.5763	.53231	.53941	.64303	.60755
28	.012641	0.4235	0.4275	.4837	0.4570	.47404	.48036	.57264	.54103
29	.011257	0.3358	0.3389	.3835	0.3624	.42214	.42777	.50994	.48180
30	.010025	0.2663	0.2688	.3042	0.2874	.37594	.38095	.45413	.42907
31	.008928	0.2113	0.2132	.2413	0.2280	.3348	.33926	.40444	.38212
32	.007950	0.1675	0.1691	.1913	0.1808	.29813	.3021	.36014	.34026
33	.007080	0.1328	0.1341	.1517	0.1434	2655	.26904	.32072	.30302
34	.006304	0.1053	0.1063	.1204	0.1137	.2364	.23955	.28557	.26981
35	.005614	0.08366	0.08445	.0956	0.9015	.21053	.21333	.25431	.24028
36	.005000	.06625	.06687	.0757	.0715	.1875	.19	.2265	.2140
37	.004453	.05255	.05304	.06003	.05671	.16699	.16921	.20172	.19059
38	.003965	.04166	.04205	.04758	.04496	.14869	.15067	.17961	.16973
39	.003531	.03305	.03336	.03755	.03566	.13241	.13418	.15995	.1511
40	.003144	.02620	.02644	.02992	.02827	.1179	.11947	.14242	.13456
Specific grav.		7.7747	7.847	8.880	8.386	7.200	7.296	8.698	8.218
Weight per cubic foot		185.874	90.45	554.988	524.16	450.	456.	543.6	513.6

Rules for Speed.

To find speed of counter-shaft in accordance with main shaft and machine.—Subtract the number of revolutions of the main shaft from the number of revolutions the machine should make; divide the remainder by two. The quotient will show the number of revolutions of the countershaft.

Example.—The main shaft runs 200 revolutions per minute, while the machine should run 1000 revolutions per minute. Deduct 200 from 1000, leaving 800, which divide by 2; the quotient will then be 400, which is the number of revolutions the countershaft should make.

To find diameter of pulley on the main shaft.—Multiply the diameter in inches of the receiving pulley of the countershaft by the number of revolutions the countershaft should make and divide the product by the number of revolutions the main shaft makes.

Example.—The countershaft makes 400 revolutions, the receiving pulley is $7\frac{1}{2}$ inches in diameter and the main shaft makes 200 revolutions; 400 times $7\frac{1}{2}$ equals 3000, which divided by 200 equals 15: this is the diameter in inches of the pulley on the main shaft.

To find diameter of pulley on countershaft carrying belt to machine.—Multiply the number of revolutions the machine should make by the diameter of pulley of the machine and divide by the number of revolutions the countershaft makes.

Example.—Say the machine should make 1000 revolutions, the diameter of pulley on machine being 6 inches, and the countershaft making 400 revolutions; then multiplying 1000 by 6 equals 6000: dividing this by 400 gives 15, which should be the diameter of the pulley carrying belt from countershaft to machine,

To find the speed of a machine.—Multiply the number of revolutions of the main shaft by the diameter of pulley in inches, and divide by the diameter of receiving pulley of the countershaft. The result is the speed of the countershaft. Then multiply the number of revolutions of countershaft by diameter of transmitting pulley, and divide by diameter of pulley on machine. The result will be the speed of the machine. It should be well understood that no other pulleys but those in contact with one belt should be considered.

Comparison of the Scales of the Fahrenheit, Centigrade, and Réaumur Thermometers, and Rules for Converting one Scale into another.

These three thermometers are graduated so that the range of temperature between the freezing and boiling points of water is divided by Fahrenheit's scale into 180 (from 32° to 212°), by the centigrade into 100 (from 0° to 100°), and by that of Réaumur into 80 (from 0° to 80°) portions or degrees.

The spaces occupied by a degree of each scale are consequently as $\frac{1}{9}$, $\frac{1}{5}$, and $\frac{1}{4}$ respectively, or as 1, 1.8, and 2.25; and the number of degrees denoting the same temperature, by the three scales, when reduced to a common point of departure by subtracting 32 from Fahrenheit's are as 9, 5, and 4. Hence, we derive the following equivalents:—

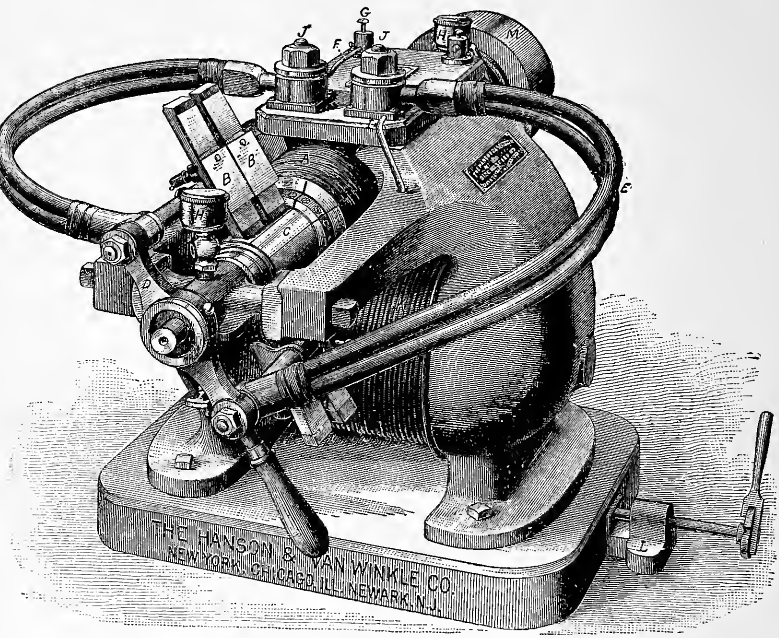
A degree of Fahrenheit's is equal to 0.5 of the centigrade or to 0.4 of Réaumur's; a degree of centigrade is equal to 1.8 of Fahrenheit's or to 0.8 of Réaumur's; and a degree of Réaumur's is equal to 2.25 of Fahrenheit's, or to 1.25 of the centigrade.

To convert degrees of Fahrenheit into the centigrade or Réaumur's, subtract 32 and multiply the remainder by $\frac{5}{9}$ for the centigrade or $\frac{4}{9}$ for Réaumur's.

To convert degrees of the centigrade or Réaumur's into Fahrenheit's, multiply the centigrade by $\frac{9}{5}$, or Réaumur's by $\frac{9}{4}$, as the case may be, and add 32 to the product.

INDEX.

The New H. & V. W. Dynamo.



We are now ready to send out eight sizes of our new and improved Dynamo, which we are safe in guaranteeing thirty per cent. more powerful than any other machine sold at same price.

The following are some of the many advantages offered:

The Field Magnets have wrought iron in them, vastly superior to cast iron.

The Magnets have a round core, which for a given amount of wire is much more powerful.

They have a very short magnetic circuit—a very good point.

The Commutator is easily taken off, so as to renew the segments, which are made of tempered copper, and are very durable.

The Armature and working parts are away from the base, and are protected fully from dirt.

The Field Magnets are wound on bobbins and are easily replaced, no return of machine and expensive repairs ever being required.

Clean lubrication, requiring attention but once a week. No oil to get in Armature like all other Dynamos.

Appearance: Without sacrificing the electrical efficiency of the machine, it is the most attractive in the market, and consequently will receive more care from those in charge.

Price List of the New Hanson & Van Winkle Dynamo.

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No. 1,	200 galls.	12 oz.	1,800	4 x 2	No. 4,	125 lbs.	$100.00
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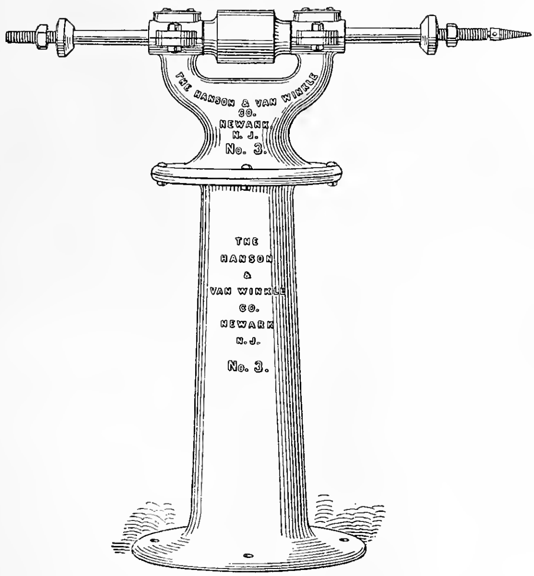

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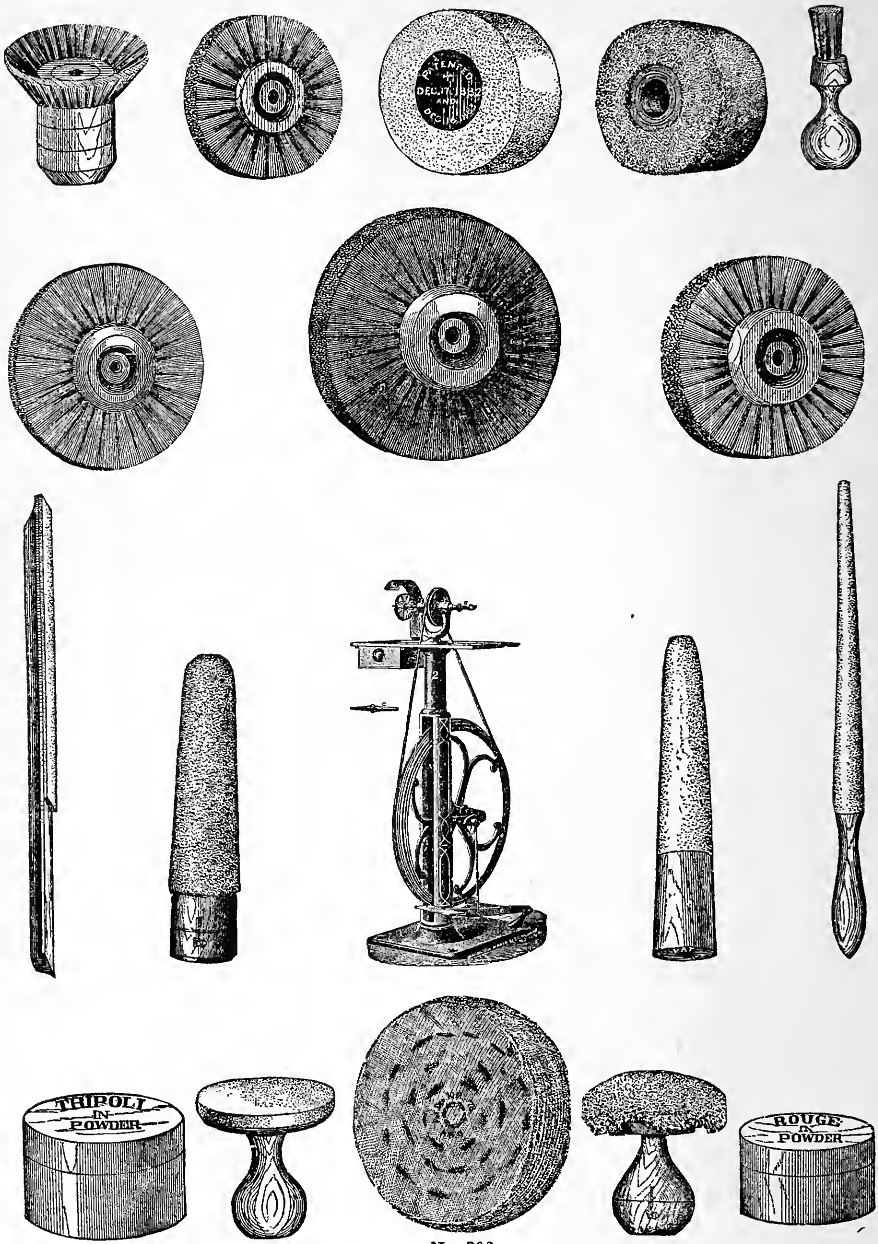

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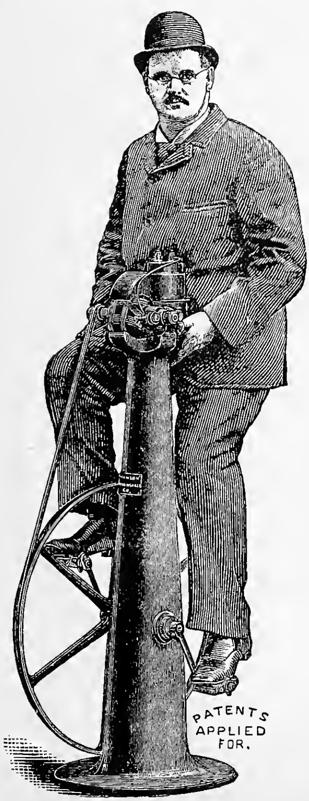

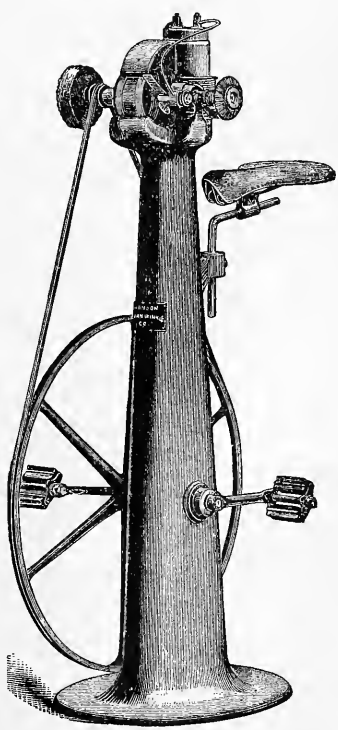

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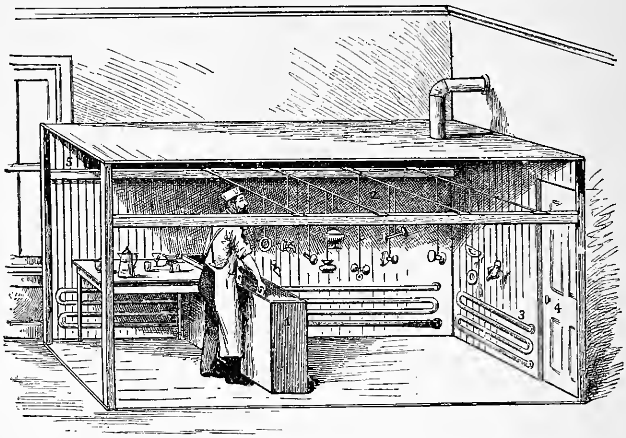

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